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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

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Biological Sciences

OBSERVATIONS OF THE WEST INDIAN MANATEE, *TRICHECHUS MANATUS*, IN TURKEY CREEK, BREVARD COUNTY, FLORIDA

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ABSTRACT: *Turkey Creek, in Palm Bay, Brevard County, Florida, was the site of a manatee study from May 1978-1979 which investigated manatee distribution, abundance and use of the area. Manatees were present during most of the year; however, in winter a change in local distribution occurred which was apparently associated with a decrease in ambient temperatures. Boat inflicted scars, barnacle and algal growths and morphological markings like tail fluke notches and skin blemishes facilitated recognition of individual animals. Increased development and recreational use posed the most obvious threats to manatees in Turkey Creek.*

THE MANATEE *(Trichechus manatus)* population in Florida is not well understood; as few as 1000 individuals may be present (Brownell et al., 1978). Manatees are found in Brevard County throughout the year and a large percentage of manatees in Florida may be located within this county (Hartman, 1979). Manatees have been reported in Turkey Creek, Palm Bay, Brevard County by Layne (1965) and Hartman (1974), but abundance in this or other parts of the county is undocumented. Investigations of the Turkey Creek area confirmed the occurrence of manatees there, and a manatee study was subsequently conducted from May 1978-1979 to investigate manatee distribution, abundance and use of the creek.

STUDY AREA—Turkey Creek is a shallow tributary of the Indian River along the east-central Atlantic coast of Florida (latitudes 28°0.8′ and 28°2.3′

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[1] Present address: 152 Greenwood Loop Road, Bricktown, New Jersey 08723.

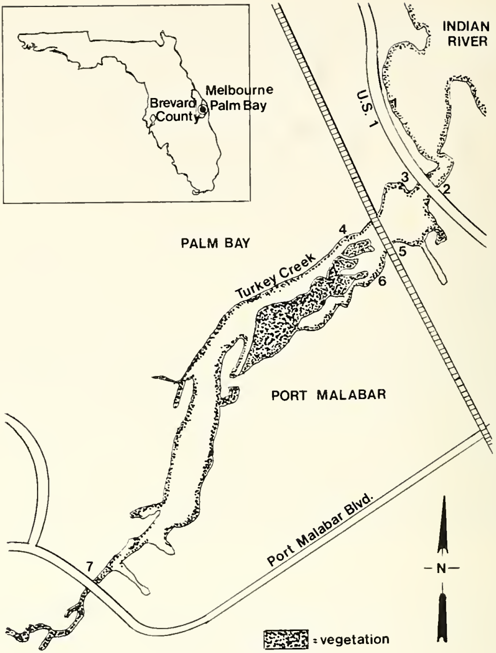


Fig. 1. Turkey Creek study area including ground survey vantage points: 1) Western shore banks; 2) U.S. 1 overpass; 3) Pelican Harbor Marina; 4) Main Street boat ramp area; 5) Railroad trestle; 6) Palm Bay Yacht Club; 7) Port Malabar Blvd. overpass area. (Insert: Location of Palm Bay, Brevard County, Florida).

North, longitudes 80°34.7′ and 80°36.3′ West). The major tributary to the creek is a drainage system of 200 km of canals (the Melbourne Tillman Drainage District). The study area (Fig. 1) extended from the mouth of the creek to the creek hammock, approximately 3 km west. The creek is estuarine at the mouth and fresh water approximately 1 km west. Vegetation in the study area included water hyacinth, *Eichhornia crassipes*; cattail, *Typha latifolia*; elephant ear, *Philodendron sp.*; and duckweed, *Lemna sp.* The creek supports little submergent vegetation other than small seasonal patches of red algae, *Gracilaria sp.* and "Florida elodea," *Hydrilla verticillata*.

Methods—Turkey Creek was surveyed for manatees 3-5 da a week during daylight hours (Fig. 2). Ground surveys were conducted from creek banks, overpasses, a railroad trestle and marina docks (Fig. 1). Boat and canoe surveys were used in areas not easily reached by foot.

Each survey lasted a minimum of 15 min per location and continued until the number of manatees present and animal activity were assessed. Data recorded included number, location, individual identifications and behavior of manatees.

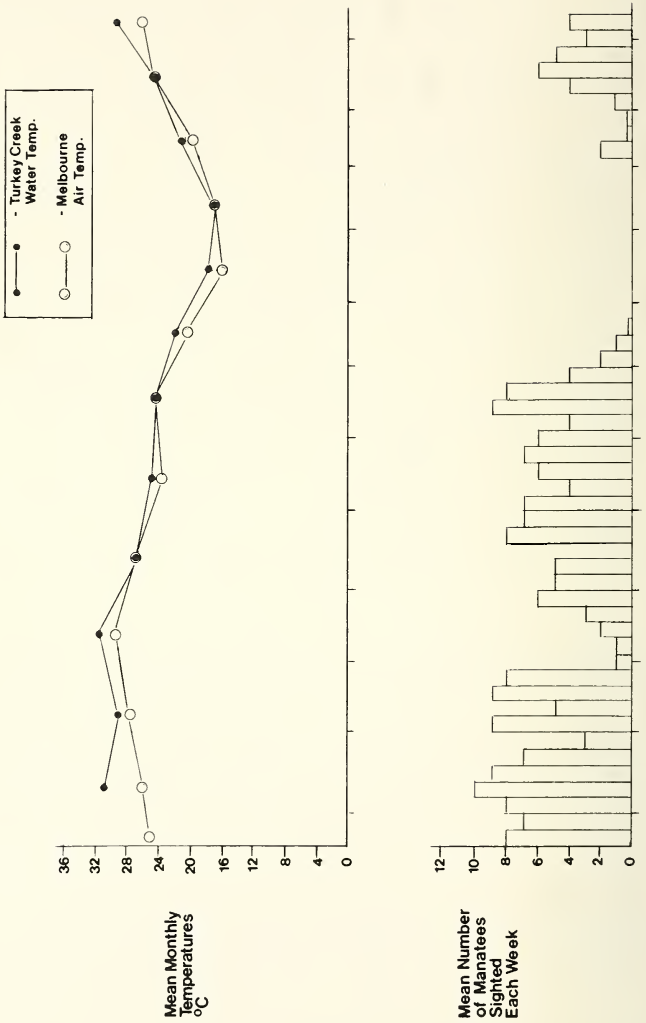
Scars from collisions with boat propellers or skegs and notches and tears in the tail fluke may distinctly mark manatees (Moore, 1956; Hartman, 1979) and were used to identify animals in Turkey Creek. Algal and barnacle growths and skin blemishes, although transitory markings, aided in the recognition of some manatees. Photographs were taken to aid identification of individuals. Two size classes were distinguished: calves and adults. Calves were considered to be any small manatee closely associated with another twice its length (Irvine and Campbell, 1978). Groups of manatees were distinguished from solitary animals by considering 2 or more manatees within 5 m of each other a group. Animals in groups did not necessarily demonstrate interaction.

RESULTS AND DISCUSSION — A total of 201 surveys (164 ground surveys, 37 boat/canoe surveys) was conducted in Turkey Creek, occupying 321 hr of observation. Manatees were sighted during 138 (69%) surveys. A total of 791 manatees was sighted: 775 (98%) adults and 16 (2%) calves.

Manatees were not present in Turkey Creek from 28 December 1978-3 March 1979. The absence of manatees during this period may have been associated with a decrease in ambient temperature (Fig. 2). When water temperatures decreased below a "threshold" of 20°C manatees were not likely to be present in the creek (Mann Whitney U-Test $\rho = 0.05$, $N = 51$, $Z = \pm 8.1$; Rank Correlation Coefficient Test $\rho = 0.05$, $N = 41$, $r = 0.644$).

An initial absence of manatees in Turkey Creek from 9-16 December 1978 coincided with minimum air temperatures below 10°C. From 18-26 December minimum air temperatures remained above 10°C and 1 manatee was sighted in the creek. Water temperatures during this part of December remained at or above 21°C. From 28 December 1978-3 March 1979 water temperatures ranged from 20°C-16.5°C and no manatees were sighted in Turkey Creek. When water temperatures rose above 20°C in early March (March 5) manatees were again sighted in the creek. The coldest water temperature associated with a manatee sighting was 19.5°C (17 March, 1979).

Air temperatures of 10-15°C have been reported to stimulate manatee movement to "cold spell" aggregations (Moore, 1956; Hartman, 1979). The subsequent decrease in water temperature may then increase formation of such aggregations (Hartman, 1979). Campbell and Irvine (1978) concluded that manatees congregate at "warm water refuges" such as artesian springs or warm effluents of factories and power plants when water temperatures fall below 20°C and that access to water of 20°C or higher may be a necess-


Mean Monthly Temperatures °C
36
32
28
24
20
16
12
8
4
0
Turkey Creek Water Temp.
Melbourne Air Temp.
Mean Number of Manatees Sighted Each Week
12
10
8
6
4
2
0

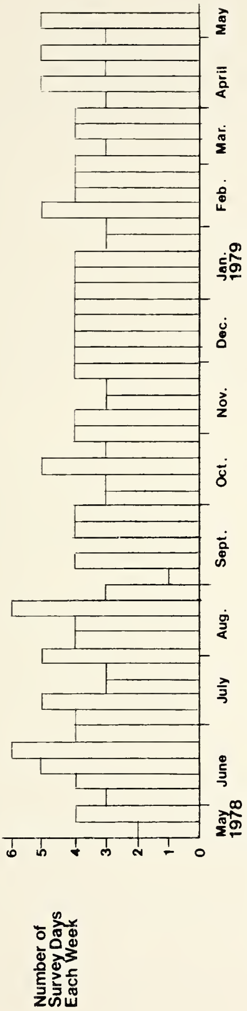


Fig. 2. Number of surveys conducted each week and mean number of manatees sighted by week in relation to mean monthly Turkey Creek water temperature and mean monthly Melbourne air temperature.

ity for manatees in Florida. The closest areas to Turkey Creek which manatees can use as "warm water refugia" are the power plants on the Indian River at Frontenac (approximately 30 km north) and Vero (approximately 30 km south).

Forty-five individual manatees (39 adults and 6 calves) were distinguished in Turkey Creek. Boat inflicted scars allowed identification of 29 (65%) of those manatees, while tail fluke tears or notches, and transient marks (algal and barnacle growths, and skin blemishes) allowed recognition of another 16 (35%). Periods of 1 wk to 3 mo between consecutive sightings of some individuals suggest that manatees moved upstream of the study area or into the Indian River. Two manatees identified in 1978 were resighted in 1979 after the winter absence of all manatees. These resightings suggest that some manatees return to the same areas in consecutive years.

Manatees were sighted at 12 locations within Turkey Creek, in salinities of 0 to 28.0 ppt. Although the physical characteristics of the study area varied little, manatees were sighted at the Pelican Harbor Marina (Fig. 1) on 132 of 138 (96%) surveys which produced manatee sightings, accounting for 605 of the 791 (76%) animals sighted. It is unclear what caused manatees to apparently prefer this area; however, manatees are often observed around marinas.

Manatees were encountered alone or in small groups, usually consisting of 2 or 3 animals (mean group size = 2.9 animals). Most groups appeared to last briefly (up to 15 min), and animals often moved into and out of groups. Cow-calf pairs were observed on 13 surveys and calves were also seen alone on 2 occasions. Unlike other groups, cow-calf pairs remained together for the duration of observation time.

Interactions observed between manatees included muzzle contact, embracing with flippers and synchronous breathing. Manatees sometimes swam in follow-the-leader formations, swam in circles, rolled from belly to back, and vigorously chased other manatees. These activities often appeared play-like, but because of a lack of knowledge concerning "normal" manatee behavior such activities are best classified as displays of synchronization and coordination (Reynolds, in press).

Manatees fed on water hyacinth (*Eichhornia crassipes)* and cattail (*Typha latifolia)* most often (75% of observed feeding time). It is not certain whether these observations reflect a true apportionment of food preferences because these 2 plants were also the most visible plants in Turkey Creek. Manatees also fed on duckweed (*Lemna sp.)*, unidentified green algae on pilings and boat bottoms and overhanging lawn grass.

Human activities affected manatees in Turkey Creek. The tremendous growth of Palm Bay is resulting in increased development and recreational use along the creek. The construction of Pelican Harbor Marina (Fig. 1) and construction of a lock and dam system upstream of the study area have resulted in increased boating in the creek. The lock and dam may be a threat to manatees who venture too close; in Dade County manatees have been en-trapped and killed by similar structures (Odell and Reynolds, 1979). Collisions with boats and barges are well-documented as another cause of manatee mortality in Florida (Irvine, Odell and Campbell, 1978; Odell and Reynolds, 1979). According to U.S. Fish and Wildlife Service data collected from April 1974-March 1981 approximately 22% of manatee mortality in Florida and 26% in Brevard County was boat/barge inflicted (Tom O'Shea, pers. comm.). Boats traveling at excessive speeds posed the most obvious threat to manatees in Turkey Creek. Boats nearly hitting manatees and manatees with fresh scars were visible evidence of the impact of boating on manatees.

The Melbourne Tillman Drainage Control District uses 2,4-D annually in Turkey Creek to control aquatic weeds, mainly the water hyacinth (Fridersdorff and Pierce, 1981). 2,4-D use affected manatees by reducing available food supplies. Bioconcentration of contaminants associated with 2,4-D and its degradation products may occur in manatees because animals ingested the sprayed plants; however, no data presently exists to substantiate this concern. Furthermore, 2,4-D may not be of concern because it breaks down rapidly in aquatic environments (Watson, 1977; Friedersdorff and Pierce, 1981) and no adverse affects on animal health have been associated with worldwide 2,4-D use (Ware, 1978). Weed removal around boat docks and ramps also decreased food supplies available to manatees in Turkey Creek.

SUMMARY — Much remains to be learned about the West Indian manatee, *Trichechus manatus*. Observations of manatees in Turkey Creek revealed that manatees were present throughout most of the year but that a distribution change apparently related to a decrease in ambient temperature occurred in winter. Forty-five different manatees were identified; 39 adults and 6 calves. Manatees were observed alone and in small groups, usually consisting of 2 or 3 animals. Further knowledge and understanding of manatee distribution and abundance is important for future land use planning to minimize human impacts on manatees and their habitats.

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Biological Sciences

NEW DISTRIBUTIONAL RECORDS FOR NON-NATIVE FISHES IN FLORIDA

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ABSTRACT: *Three species of cichlid fishes* (Cichlasoma octofasciatum, Tilapia melanotheron, *and* T. mossambica) *and 2 poeciliid species* (Xiphophorus maculatus *and* X. helleri) *have been introduced recently into the coastal canals and waterways of the Banana-Indian River estuary near Satellite Beach, Brevard County, Florida. Collections taken during 1980 and 1981 indicate that the cichlids are firmly established, rapidly expanding their ranges, and capable of tolerating saline conditions and low water temperatures. Of immediate concern is the possibility of the detrimental impact on commercially-important native species, which use the estuaries as nursery grounds.*

THE impact of exotic fishes on native species is increasingly recognized as a serious problem that requires further study and documentation. Recent works on exotics in Florida include those of Courtenay and Hensley (1979), Courtenay et al. (1980), Miley (1978), and Hogg (1976). Exotic fish species are usually introduced into new environments by attempts to establish commercial or sport fisheries, and by accidental or intentional releases by home aquarists and fish breeders.

We give new distributional records for established populations of 3 cichlid fishes — the Jack Dempsey, *Cichlasoma octofasciatum*; the blackchin tilapia, *Tilapia melanotheron*; the Mozambique tilapia, *Tilapia mossambica* and 2 poeciliids, the southern platyfish, *Xiphophorus maculatus*; and the green swordtail, *X. helleri* — in Brevard County, Florida. All 5 are known elsewhere in Florida (*C. octofasciatum* from Dade and Hillsborough counties; *T. mossambica* from Dade County; *T. melanotheron* from Hillsborough and Manatee counties; *X. maculatus* and *X. helleri* from Hillsborough County). *Tilapia mossambica* and *X. maculatus* were reported from Brevard County by Courtenay et al. (1980) and Courtenay and Hensley (1979), respectively.

COLLECTIONS — Fish collections were made with a variety of seines, gill nets, and cast nets at locations indicated in Fig. 1. Abundance data on sympatric species are available from the authors.

FAU 80-1. Satellite Beach, just W of County Road 3-B in canal draining Satellite Beach Civic Center pond, 21 Feb 1980.

FAU 80-2. South Patrick, east-west canal crossing County Road 3-B 50m N of St. George Street, 21 Feb 1980.

FAU 80-33. Satellite Beach, east-west canal at bridge on County Road C-3B, 1.2 km N of Eau Galle Causeway, 8 July 1980.

FAU 80-34. Indian Harbor Beach, backwater cove connected to Indian River, about 20 m W of County Road C-3B and .75 km S of State Road 518, 8 July 1980.

FAU 80-35 A and B. Satellite Beach. FAU 80-35A was the same locality as FAU 80-1, while FAU 80-35 B was located on the E side of C-3B, separated from FAU-35A by a culvert, 9 July 1980.

FAU 80-36. South Patrick, junction of 9-Mile Canal (Grand Canal) and Banana River, SE of Pineda Causeway (State Road 404), 9 July 1980.

FAU 80-57. Same locality as FAU 80-34, 11 Dec 1980.

FAU 80-58. Same locality as FAU 80-2, 12 Dec 1980.

FAU 80-59. Indian Harbor Beach, residential canal just W of County Road 3-B, 1.5 km N of State Road 516 (Melbourne Causeway), 11 Dec 1980.

FAU 81-2. Patrick Air Force Base Golf Course, ponds and canal emptying into Banana River, NE of Pineda Causeway (State Road, 404), 22 April 1981.

FAU 81-3. Same locality as FAU 80-2 and FAU 80-58, 23 April 1981.

FAU 81-4. Same locality as FAU 80-35B, 23 April 1981.

CICHLASOMA OCTOFASCIATUM

In collection FAU 80-33, *Cichlasoma octofasciatum* (Jack Dempsey) comprised 3.4% by number (15 individuals; 18-116 mm standard length), and 15.4% by weight of the total fish fauna collected. Specimens were seined from shallow water (0-1 m in depth) and undercut banks with dense littoral vegetation. Salinities ranged from 2 to 8 ppt. The species was not observed or collected in adjacent (higher saline) canals. Common sympatric species were *Gambusia affinis*, *Menidia beryllina* and *Poecilia latipinna* (subadult *Tilapia melanotheron* were quite common also, but eluded capture).

Collection FAU 80-35B contained 9 individuals (73-117 mm S.L.) of *C. octofasciatum* (8.3% by number, 79.6% by weight). Specimens seeking refuge in overhanging vegetation were captured by dragging the seine

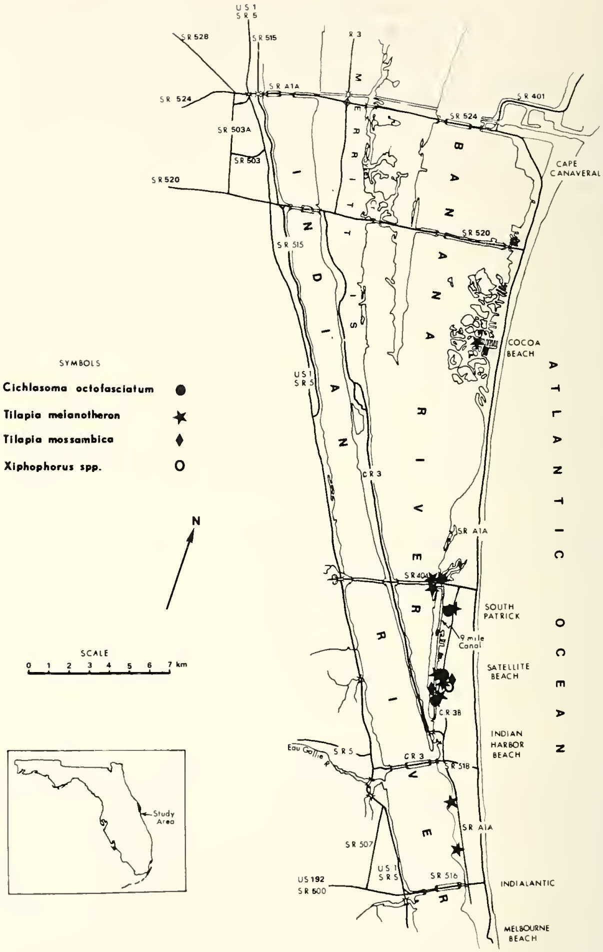

Fig. 1. Collection sites for non-native fishes in Brevard County, Florida.

through the vegetation. The salinity was 2 ppt. Common sympatric species were *Gambusia affinis*, *Lucania parva*, and *Poecilia latipinna* (subadult *Tilapia melanotheron* were quite common here also, but again eluded capture). In collection FAU 81-4, at the same locality, the salinity was 0 ppt and 8 *C. octofasciatum* were taken.

One specimen of *C. octofasciatum* was cast netted at locality FAU 81-3, representing a new distributional record. All 3 collection sites are connected by the brackish 9-mile Canal and may represent separate introductions or parts of a single expanding population. The Brevard County population(s) are not contiguous with other Florida populations, and probably are the result of release by home aquarists.

TILAPIA MOSSAMBICA

Prior to our collections, *Tilapia mossambica* was reported to be established in the Banana River adjacent to Cocoa Beach (Courtenay et al., 1980). Actual abundance of this species is obscured by the probable confusion by commercial fishermen of *T. mossambica* with *T. melanotheron*. Adult Mozambique tilapia were observed in the Satellite Beach Civic Center pond and collected in the adjacent brackish water canal (FAU 80-35B, FAU 81-4), as well as in a low-salinity canal about 1 km south of the Civic Center (FAU 80-33). At the latter locality (salinity 8 ppt), a single adult *T. mossambica* (200 mm S.L., 320 g by weight) was captured; no juveniles were seen or collected.

TILAPIA MELANOTHERON

Tilapia melanotheron is established in the Banana and Indian Rivers from Cocoa Beach south to Indian Harbor Beach (Fig. 1). Mullet fishermen have reported catching *T. melanotheron* (or misidentified *T. mossambica)* for the past 3 yr. Collections and observations indicate that it is most abundant in shallow estuarine waters, coastal lagoons, and canal systems, similar to those occupied in its native range (see Thys van den Audenaerde, 1971; Fagade, 1971).

In an oligohaline canal (FAU 80-2, Fig. 1), *T. melanotheron* were caught totaling 1.56 kg (41-182 mm S.L.). At this locality juveniles were closely associated with marginal vegetation, while large schools of adults and subadults were observed feeding over shallow sand bars. The most common sympatric species were *Gambusia affinis*, *Heterandria formosa*, and *Poecilia latipinna*. In later collections (FAU 80-56, FAU 81-3) from the same locality, *T. melanotheron* were noticeably more abundant, and totalled 5.4 kg (77-160 mm S.L.), and 4.4 kg (59-177 mm S.L.), respectively.

In a freshwater pond and canal emptying into the Banana River (FAU 81-2), 8 individuals were captured, (1.7 kg, 130-179 mm S.L.). Local hook and line fishermen were observed taking the blackchin tilapia with worms.

Schools of juvenile *T. melanotheron* were observed or collected in seagrass beds (*Halodule wrightii* and *Syringodium filiforme)* at several localities from Cocoa Beach to South Patrick (Fig. 1) in our July 1980 collections, however; they were not collected or observed here during the April 1981 survey. In collection FAU 80-36 (salinity 30 ppt; 94°F), *T. melanotheron* comprised 2.1% by number (2 individuals; 50-62 mm S.L.), and 7.4% by weight. These percentages are low due to difficulty in capturing of this species and therefore represent an underestimate of the population at this particular location. Common sympatric species were *Floridichthys carpio*, *Fundulus grandis*, *Menidia beryllina*, and *Poecilia latipinna*. Mullet fishermen have reported taking large numbers of *T. melanotheron* in seagrass beds near mouths of canals on the Banana River (Carver and Sons Seafood Market, pers. comm.) and in Sykes Creek during late spring and summer.

Tilapia melanotheron were collected in a small backwater lagoon adjacent to Indian River (FAU 80-34, FAU 80-57; Fig. 1) where salinity measured 23 ppt. In collection FAU 80-34 this species comprised 2% of the sample by number (4 individuals; 55-57 mm S.L.) and 4.9% by weight; most common associated species were *Elops saurus*, *Gambusia affinis*, *Poecilia latipinna*, and *Strongylura notata*.

In collection FAU 80-35A (salinity 8 ppt), just downstream of the Satellite Beach Civic Center pond, *T. melanotheron* comprised 1.5% by number (3 individuals; 112-133 mm S.L.) and 35.5% by weight. One individual was cast netted here in an earlier collection (FAU 80-1). Collection FAU 81-4 contained 21 individuals from the Civic Center pond and adjacent canal. Many others were seen on both sampling dates, but eluded capture due to their pelagic schooling behavior.

The introduction of this species probably occurred near the Satellite Beach Civic Center; densities of this species are greatest here and in the South Patrick east-west canal (FAU 80-2).

XIPHOPHORUS MACULATUS AND X. HELLERI

These species were collected only at the Satellite Beach Civic Center Pond (FAU 80-1, FAU 81-4). *Xiphophorus maculatus* was reported from the area previously (Courtenay and Hensley, 1979), while the collection of *X. helleri* represents a new record for Brevard County. Both species are established as individuals of all sizes were collected.

DISCUSSION—In its native range (Atlantic slope drainages from Veracruz, Mexico to Honduras), *Cichlasoma octofasciatum* often comprises a large portion of the fish community and occurs in a wide variety of habitats (Courtenay et al., 1980). Tolerances for low oxygen concentrations, variable temperatures, differing substrates, and high turbidities (Courtenay et al., 1980) suggest that most of Florida's freshwater habitats could potentially support populations of this species; however, there seems to be a preference by the species for eutrophic areas with dense vegetation. We were unable to locate any information on salinity tolerances for this species, nor is any literature available on interactions with native centrarchids, although, as their common name implies, Jack Dempseys are known among aquarists for their pugnacious behavior.

Low water temperature may prove to be the most important factor limiting dispersal of this species. Shafland and Pestrak (MS in press) predict that winter stream temperatures suitable for Jack Dempseys exist in all but northwestern Florida. Its sedentary, secretive nature may act as a further check to dispersal.

Both *Tilapia melanotheron* and *T. mossambica* are extremely tolerant of high salinities and show a preference for estuarine conditions in their native ranges (African Gold Coast [Ghana], and southeastern Africa [Mozambique], respectively; Thys van den Audenaerde, 1971). Salinities in the Banana River range from 9.3 to 34.5 ppt ($\bar{x}$ = 21.8 ppt; Gilmore, 1977). In aquaria, *T. melanotheron* is capable of spawning in salinities of 34 ppt (Finucane and Rinckey, 1965). In California, *T. mossambica* has been found breeding and larvae have been collected in salinities as high as 34.5 ppt (Knaggs, 1977). Exotic fishes that are so successful in estuaries should be of concern in Florida and other southern coastal regions because of the large expanses of this habitat available.

Present abundance data and conversations with local fishermen in Brevard County indicate that *T. melanotheron* is rapidly expanding its range, while the status of *T. mossambica* remains unclear at this time. *Tilapia melanotheron* has been established along the eastern side of Tampa Bay since 1958 and is sufficiently abundant to support a small commercial fishery (18,000 Kg in 1968, Buntz and Manooch, 1969). It is suspected that a commercial fishery will soon be established in the Banana and Indian rivers. Commercial fishermen in North Melbourne have caught *T. melanotheron* in their mullet nets with increasing frequency over the past 3 yr during the summer. A single catch of 200 lbs in one 50 min set of a 400′ gill net was reported near South Patrick in the Banana River (Alcee Taylor of Carver and Sons Seafood Market, pers. comm.). In Hillsborough County, this species has also penetrated the headwaters of the Alafia River and has become the dominant species in Lithia Springs, while native centrarchid abundances are well below those expected (Courtenay et al., 1974) indicating that it may be a threat to native freshwater fishes. Those authors noted a markedly reduced vegetation cover at Lithia Springs, which they attributed to grazing by *T. melanotheron*, and did not rule out competition for spawning sites as a reason for attaining dominance over native species.

Tilapia mossambica has been described as omnivorous, feeding on a wide variety of plant and animal matter ranging in size from algae and detritus to rooted aquatic plants, earthworms, and small fish. Additionally, there is evidence that the species undergoes ontogenetic changes in feeding, although statements on these changes are contradictory (Courtenay and Hensley, 1979). On the other hand, *T. melanotheron* was found to feed primarily on detritus and phytoplankton, with no evidence that it consumed fishes, crustaceans or molluscs in Tampa Bay (Finucane and Rinckey, 1964). There is therefore a good possibility of diet overlap between these *Tilapia* species and native estuarine fishes, many of which are bottom feeders.

The greatest obstacle to northward expansion of these 2 species is low temperature. Based on temperature tolerance determinations, Shafland and Pestrak (MS in press) predict that suitable water temperatures may exist as far as Daytona Beach, Volusia County for *T. melanotheron* and Gainesville, Alachua County, for *T. mossambica.* However, survival in cooler climates may be possible in thermal springs, reservoirs with heated effluents, or other habitats with warmwater conditions year round. The moderating effect of salinity on lower lethal temperature tolerances, as shown by Allanson et al. (1971) for *T. mossambica*, may allow further northward expansion in brackish and marine waters. Their survival during the cold winter of 1981 (8-14°C; pers. comm. Conrad White, Brevard Co. Health Department) further supports these findings. No such temperature barriers occur to the south.

Unlike the cichlids, *Xiphophorus* spp are relatively stenohaline, requiring very low salinities and would therefore not be expected to populate estuarine waters. The effects of these fish on native freshwater fishes are unknown.

The *X. maculatus* population in the Satellite Beach Civic Center Pond appears to have increased over the past 2 yr; however, this may reflect seasonal reproductive peaks, since collection FAU 80-1 was made in February and FAU 80-4 was a spring collection. In FAU 80-1 only 3 were collected following extensive seining, while 44 individuals were easily collected in FAU 81-4.

The *Tilapia* species may have been introduced by local fishermen with the intent of creating a commercial fishery similar to the *T. melanotheron* and *T. aurea* fisheries in Tampa Bay. Introduction of the *Xiphophorus* and *Cichlasoma* species probably represent releases by home aquarists.

We know very little about the biological effects of these species in Florida's estuaries. Of immediate concern is the possibility of detrimental effects of *Tilapia* spp on native estuarine species, as has occurred in California (Knaggs, 1977).

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Biological Sciences

USE OF A SIMPLE WATER COLUMN SAMPLER TO MONITOR CHEMICAL AND BIOLOGICAL CONDITIONS IN SHALLOW WATERS

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ABSTRACT: *Field studies in a shallow lagoon indicated that quantitatively reliable estimates of inorganic nutrients, active phytoplankton chlorophyll a, and copepod nauplii can be obtained with a tube-type sampler. Samples collected in shallow, well-mixed water by a water column sampler (= 7.62-cm ID, 4.57 m long, 0.021 m^3 capacity—PVC tube) and a discrete-depth sampler (= 7.62-cm ID, 0.49 m long, 0.005 m^3 capacity—Niskin bottle) were statistically similar. The number of copepod nauplii captured in the tube sampler was significantly greater (ca. 2X) than the densities obtained in a 25-cm ID, 64-μm mesh net.*

THE selection of a device to sample chemical and biological parameters in aquatic habitats is often a compromise between how many samples are needed to adequately estimate natural variability in time and space versus how much time and manpower are required to collect and process the data obtained. For example, water samplers of various designs have been used to estimate nutrients and plankton concentrations in shallow water environments (Schwoerbel, 1970). Most of these studies have used discrete-depth samplers (= bottles) to examine vertical and horizontal variability. Some investigations have utilized interval-depth samplers (= tubes) which isolate a vertical portion of the water column when less detailed measurements are required (Lund et al., 1958; Hair et al., 1968; Landry, 1978). Previous studies of water samples collected with bottles and tubes have indicated that profiles of hydrographic features and density estimates of pelagic organisms do not differ significantly (Gilbert and Miller, 1976; George and Owen, 1978; Irish, 1980). Comparisons of samples from depth intervals to samples from a point or points within the depth ranges have at least 2 weaknesses. First, the selection of a depth within a water column is often standardized without regard to chemical and biological processes that vary on temporal and spatial scales. The choice of appropriate sampling sites is therefore arbitrary in the sense that the range of variability measured may differ with each set of depths chosen. Second, data from depth intervals are not strictly comparable to data from discrete depths.

We describe a simple method for comparing data derived from interval-depth and discrete-depth sampling and discuss the advantages of using a tube sampler in shallow, well-mixed waters.

METHODS—All samples were collected in the Indian River lagoon, a shallow (mean depth = 1.5 m) waterway adjacent to the barrier islands along the eastern coast of central Florida. Generally, winds and tidal action kept the water column well-mixed throughout the year. However, seasonally heavy rainfall and the discharge of fresh water from flood control canals occasionally produced short-term vertical stratifications in salinity and inorganic nutrient concentrations.

The rigid tube sampler (7.62-cm ID, 4.57 m long, 0.021 m^3 capacity) used in this study is shown in Fig. 1. An early model of this device had a rubber "plumber's helper" as the closure on the lower end. The mouth openings at each end of this prototype were of equal diameter. While testing this design we found we could not always rely on a leakproof seal at the closing end. Consequently, the original closure was replaced with a 5.08-cm ball valve. This smaller opening does not affect appreciably the flow rate of water entering the 7.62-cm dia tube if it is lowered slowly (ca. 30-60 cm/sec) into the water. Calculations of conduit flow indicate that at a more rapid descent the tube will not fill at an even rate and most of the water entering the device will be from near the bottom (Welty et al., 1976). Two samples were collected for each of 4 depth intervals (i.e., 0-0.9, 0-1.8, 0-2.7, and 0-3.7 m).

The Niskin bottle (7.62-cm ID, 0.49 m long) used was a standard 5-ℓ sampler (General Oceanics Model 1010). Two samples were collected at 5 depth levels (i.e., surface (0-20 cm), 0.9, 1.8, 2.7 and 3.7 m).

Water collected in each of the samplers was drained separately into a graduated polyethylene bucket to allow thorough mixing. Four, 250-mℓ aliquots were removed from this bucket for measurements of inorganic

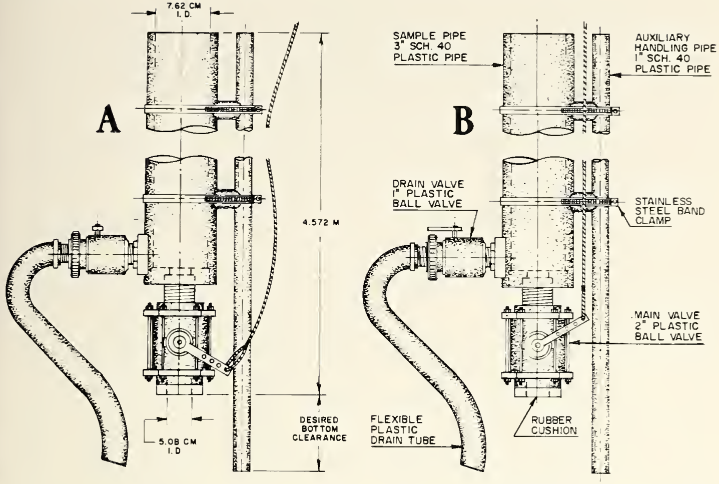

Fig. 1. Rigid tube sampler. (A) Main valve open, drain closed. (B) Main valve closed, drain valve open.

nutrients. Concentrations of silicate, nitrite, nitrite + nitrate, ammonia and orthophosphate were measured in 2 subsamples of each sample with an autoanalyzer (Technicon Model AA II). Three, 1-ℓ aliquots were also drawn from the bucket to determine active phytoplankton chlorophyll *a* by spectrophotometric (Varian Model 365) methods (Anonymous, 1966; Strickland and Parsons, 1968).

Additional samples, gathered with the tube and a vertically-hauled, 25-cm dia net (64-μm mesh), were poured through 202 and 20-μm mesh screens to select and concentrate copepod nauplii. Water volumes for plankton net hauls were determined with a flowmeter (General Oceanics Model 2030). Copepod nauplii were subsampled with a 1-mℓ Stempel pipette and counted in a Sedgwick-Rafter chamber. At least 500 nauplii were contained in each sample.

Salinity was measured with an inductive salinometer (Plessey Model 6230), an *in situ* water quality instrument (Hydrolab Model D) and a refractometer (American Optical Model 10419).

All water samples discussed in this paper were collected at the same site (27°28′ Lat., 80°19.5′ Long.). Well-mixed waters were sampled in February and June. A stratified water column was studied in September (Table 1 and Fig. 2).

To statistically compare interval-depth with discrete-depth samples the values obtained from bottle samples were regressed on depth, both linearly and exponentially, to derive integral mean values. There was no apparent

Table 1. A comparison of inorganic nutrient (μg-at•l^{-1}) and active chlorophyll *a* (mg•m^{-3}) values collected with tube and bottle samplers—[(*) denotes significant difference at 95% level].

		TUBE SAMPLER				NISKIN BOTTLE				NISKIN (surface extrapolated)			
Parameter	Depth Interval (m)	n	x	s	95% Confidence Interval	n	integral x	s	95% Confidence Interval	n	integral x	s	95% Confidence Interval
silicate	0-0.9	8	88.88	24.12	68.71 - 109.05	16	127.26	85.81	81.55 - 172.98	8	62.70	11.14	53.39 - 72.01
	0-1.8	8	55.95	9.57	47.96 - 63.94	24	100.60*	78.99	67.55 - 133.96	16	57.78	9.66	52.63 - 62.93
	0-2.7	8	45.00	6.97	39.16 - 50.84	32	85.95*	72.77	59.70 - 112.19	24	52.53	10.97	47.90 - 57.16
	0-3.7	8	45.29	1.97	43.63 - 46.95	40	77.22*	67.24	55.71 - 98.73	32	49.97	10.48	46.19 - 53.75
nitrite	0-0.9	8	0.76	0.06	0.71 - 0.81	16	0.87	0.21	0.76 - 0.98	8	0.68	0.10	0.60 - 0.76
	0-1.8	8	0.63	0.04	0.61 - 0.65	24	0.78*	0.21	0.69 - 0.87	16	0.65	0.08	0.61 - 0.69
	0-2.7	8	0.57	0.09	0.50 - 0.64	32	0.73*	0.20	0.66 - 0.80	24	0.62	0.08	0.59 - 0.65
	0-3.7	8	0.58	0.01	0.56 - 0.60	40	0.70	0.19	0.64 - 0.76	32	0.61	0.07	0.58 - 0.64
nitrite & nitrate	0-0.9	8	9.89	6.51	4.45 - 15.33	16	11.77	6.36	8.38 - 15.16	8	8.98	3.64	5.94 - 12.02
	0-1.8	8	7.52	4.84	3.48 - 11.56	24	9.57	6.06	7.01 - 12.13	16	7.08	3.24	5.35 - 8.81
	0-2.7	8	4.33	0.56	3.86 - 4.80	32	8.17*	5.62	6.14 - 10.20	24	6.08*	2.99	4.82 - 7.34
	0-3.7	8	4.67	0.51	4.24 - 5.10	40	7.32*	5.29	5.63 - 9.01	32	5.55	2.74	4.56 - 6.54
ammonia	0-0.9	8	13.09	8.19	6.24 - 19.94	16	20.77	13.94	13.34 - 28.20	8	8.61	0.50	8.57 - 9.65
	0-1.8	8	8.01	0.86	7.30 - 8.72	24	17.99*	12.73	12.61 - 23.37	16	10.52	5.78	7.44 - 13.60
	0-2.7	8	8.04	1.19	7.05 - 9.03	32	15.36*	11.90	11.07 - 19.95	24	9.50	4.89	7.43 - 11.57
	0-3.7	8	8.07	0.93	7.29 - 8.85	40	13.81	11.07	10.27 - 17.35	32	9.03	4.30	7.48 - 10.58
orthophosphate	0-0.9	7	2.59	0.42	2.20 - 2.98	15	4.98	3.76	2.09 - 7.06	8	1.88	0.48	1.48 - 2.28
	0-1.8	8	1.67	0.31	1.41 - 1.93	22	4.21*	3.61	2.61 - 5.81	15	2.20	1.91	1.14 - 3.26
	0-2.7	8	1.32	0.31	1.06 - 1.58	30	3.43*	3.35	2.18 - 4.68	23	1.88	1.59	1.19 - 2.57
	0-3.7	8	1.29	0.23	1.10 - 1.48	37	3.05*	3.11	2.01 - 4.09	30	1.77	1.41	1.24 - 2.30
chlorophyll *a*	0-0.9	3	7.22	0.88	5.03 - 9.41	6	5.08	2.82	2.12 - 8.04	3	7.01	2.77	0.13 - 13.89
	0-1.8	3	12.00	1.41	8.50 - 15.50	9	7.55	4.29	4.25 - 10.65	6	9.76	3.45	6.14 - 13.38
	0-2.7	3	7.42	3.52	0.00 - 16.16	12	7.51	3.77	5.11 - 9.91	9	8.97	3.14	6.56 - 11.38
	0-3.7	3	7.68	3.13	0.00 - 15.46	15	7.47	3.51	5.53 - 9.41	12	8.69	2.76	6.94 - 10.44

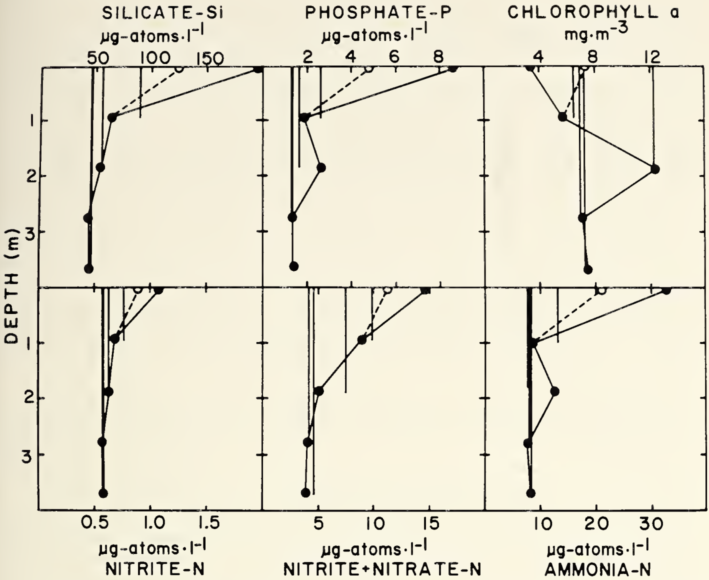

FIG. 2. Concentrations of inorganic nutrients and active phytoplankton chlorophyll *a* from samples collected with a tube sampler (vertical lines, mean values) and a Niskin sampler (closed circles, mean values; open circles, extrapolated mean values).

difference between empirically-formed functions for these regression curves. Therefore, integral means were determined by interpolation to correspond to depth intervals sampled by the tube.

RESULTS AND DISCUSSION — Samples were collected when the water column was well-mixed and when stratified in order to obtain data that would demonstrate if differences between interval-depth and discrete-depth sampling could be detected. Tube and bottle data from well-mixed water were similar statistically and are not shown here ($P<0.05$, Student's t-test). The data presented are from hydrographically stratified water and serve to indicate how samples compared under these conditions and to illustrate some unexpected results.

When lower salinity (7-10‰), nutrient-rich, surface water (0-20 cm) occurred above higher salinity (19-26‰), nutrient-poor water (ca. 4 m deep) (Fig. 2), inorganic nutrient concentrations from bottle samples were significantly larger than the tube samples ($P<0.05$, Student's t-test) for all but the 0-0.9 m interval where the 95% confidence intervals overlapped (Table 1). The primary cause of this difference was the high, inorganic nutrient concentration in the surface layer. To account for this bias, nutrient values from the surface water were excluded (n = 8) and integral means were extrapolated by regressing the deeper discrete-depth values to the surface. This treatment eliminated all but one of the significant differences between sample means (i.e., the nitrite + nitrate value for the 0-2.7 m interval). The persistence of this result is probably related to the narrow horizontal concentration of this nutrient. Inorganic nutrient concentrations may also be affected by chemical precipitation and adsorption processes when waters of different salinities are mixed. Up to 10% of the silicate-silica in estuarine and river plume areas may be removed by these processes according to Bien et al. (1958); and Burton et al. (1970). However, Fanning and Pilson (1973) concluded from field and laboratory studies that silicate-silica was released rather than adsorbed during mixing conditions. We are unaware of similar investigations on other nutrients. Because we measured only dissolved inorganic nutrients, we suggest that a tube sampler be used only in well-mixed, unstratified waters unless dissolved and particulate nutrient fractions are determined.

Active phytoplankton chlorophyll *a* values were not significantly different (Table 1).

Densities of copepod nauplii, the most abundant animals collected with both the tube sampler and the plankton net, are compared in Table 2. Catches with the tube were statistically similar regardless of the water volume collected (i.e., the 95% confidence limits overlapped). These densities were about 40% greater than the mean densities of the plankton net collections. This difference can be attributed to the passage of small copepod nauplii through the larger mesh of the plankton net (= 64-μm versus 20-μm mesh for water from tube sampler). Hopkins (1977) reported that 28-μm mesh retained about 30% more zooplankton than 64-μm mesh netting. Landry (1978) noted that copepods collected with a tube sampler and concentrated on 53-μm mesh were 2-4X more numerous than catches taken with 25-cm ring nets or Van Dorn bottle casts. The important point to consider

TABLE 2. A comparison of the mean densities of copepod nauplii collected with a 7.62-cm ID tube sampler and a 25-cm ID, 64-μm mesh plankton net (n = 3 replicate samples per volume).

Mean Volume of Water Sampled (ℓ)	Mean Density ± s X 10^5 per m^3	95% Confidence Interval
	TUBE SAMPLER	
14	7.18 ± 0.80	5.19 - 9.17
26	5.80 ± 0.33	4.98 - 6.62
55	6.22 ± 0.31	5.45 - 6.99
118	5.60 ± 0.42	4.56 - 6.64
	PLANKTON NET	
400	2.56 ± 0.48	1.37 - 6.64

from these data is that reliable, quantitative assessments of the density of copepod nauplii and probably other microzooplankton in shallow waters can be obtained with a tube that samples relatively small volumes of water. This is an advantage because plankton nets with mesh smaller than 64-μm are easily clogged in shallow, productive regions (Reeve, 1970). Furthermore, the time required to collect samples is reduced considerably and replicate samples are obtained easily. The simplicity of its design also makes this collecting device energy efficient and maintenance free unlike a pump sampler which requires a source of power and periodic inspection of its component parts.

Conclusions — Our results indicate that inorganic nutrients, active phytoplankton chlorophyll *a*, and copepod nauplii can be quantified from samples collected with a tube. In regions where shallow, well-mixed waters prevail the tube sampler is a simpler and more rapid alternative to sampling discrete depths with a series of closely spaced bottles.

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ICHTHYOFAUNAL ADDITIONS TO THE INDIAN RIVER LAGOON AND ADJACENT WATERS, EAST-CENTRAL FLORIDA

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Abstract: *Recent fish collections made along the coast of east-central Florida have produced 98 species previously unrecorded in this region of Florida. Twelve families have also been added to the regional check-list.*

Since the completion of the initial check-list and habitat description of the ichthyofauna of the Indian River lagoon and vicinity (Gilmore, 1977), further observations and collections have precipitated another treatment of the regional ichthyofauna. Prior to the present study, 609 species were known to occur in both fresh and marine waters at depths less than 200 m between latitude 29°05'N and 26°58'N along the east-central coast of Florida (Gilmore, 1977).

In this presentation, 98 species and 13 families are added to the ichthyofaunal check-list for east-central Florida. Three species have been recently recorded as new North American continental records, 2 species have been recently described and 2 are new species but do not have published descriptions. Most new records came from continental shelf collections and principally from reef formations.

The previously recorded 609 species and the 98 new records are not directly additive. This is partially due to the removal of some species from the 1977 check-list due to taxonomic revisions and synonomies. The previous check-list also included species whose classification at specific levels had not been determined or had not been described and are included in this presentation as new records based on recent identifications or published descriptions. The records herein bring the total Indian River regional coastal ichthyofauna to 685 species.

Methods—Specimens were collected with various fish toxicants, anesthetics, dipnets, seines, hook and line, swordfish longlines, box dredges, plankton nets, trawls, gill and trammel nets and from power plant intake screens. The power plant collections were from the Florida Power & Light Co. St. Lucie Plant on Hutchinson Island, St. Lucie County, Florida. Specimens from deep reef formations (25 to 100 m depths) were collected using lockout divers and fish toxicants ejected from JOHNSON-SEA-LINK submersibles operated by the Harbor Branch Foundation, Inc. (Gilmore et al., 1981). Systematic listings and terminology follows Robins et al. (1980).

Results and Discussion — The 98 fishes recorded as new to east-central Florida are in Table 1. Of these, *Isurus paucus* and *Gobionellus pseudofasciatus* represent recent North American continental records (Dodrill and Gilmore, 1979; Hastings, 1978). Two species, *Gymnothorax hubbsi* Böhlke and Böhlke, 1977 and *Varicus marilynae* Gilmore, 1979, were recently described from holotypes collected within the study area. Two species are new but do not have published descriptions (i.e., *Equetus* sp. nov., George Miller, pers. comm.; *Opistognathus* sp. nov., William Smith-Vaniz, pers. comm.).

Collections made on the continental shelf accounted for 90% (88 species) of the total new regional records. Most species came from the families Gobiidae (10 species), Serranidae (8 species) and Ophichthidae (6 species) and are reef associates.

Serranid captures and observations were greatly enhanced by using the JOHNSON-SEA-LINK submersible as several new records came from deep (80-100 m) *Oculina* coral reef formations (Reed, 1980). Although these deep reefs have a depauperate ichthyofauna when compared to shallower reefs, serranid diversity is high. Many serranid species found on deep coral formations apparently occupy trophic positions and microhabitats which are utilized by other species in other families on shallow reefs (1-60 m depths). Planktivorous anthiine serranids, *Hemanthias vivanus* and *Holanthias martinicensis*, form large schools over deep reefs much like clupeids, engraulids and *Chromis* spp. do over shallow reef formations. Although we have observed a specimen on a 30 m reef formation, *Holanthias martinicensis* occurs principally on reef formations at depths over 50 m. In addition to *H. martinicensis*, 5 other species *Opsanus pardus*, *Corniger spinosus*, *Chromis insolatus*, *C. scotti* and an undescribed new species *Equetus* sp. nov. (bar drum) were first recorded during deep reef submersible operations.

Other new serranid records (e.g., *Epinephelus cruentatus*, *Epinephelus adscensionis)* came from collections made on shallow to intermediate depth reef formations (1-60 m depths) and were also collected from the intake canal at the Florida Power & Light Co. St. Lucie Plant on Hutchinson Island, St. Lucie County.

Most gobiids were captured in shallow reef collections. The gobiids *Coryphopterus personatus*, *C. punctipectophorus*, *Lythrypnus spilus*, *Nes longus* and *Ioglossus calliurus* were collected from these shallow reefs. A new gobiid species, *Varicus marilynae* was described based on a specimen collected by dredge in shell rubble near a deep *Oculina* coral reef at a depth of 61-79 m (Gilmore, 1979). A specimen of *Psilotris* was collected but due to its damaged condition the species could not be determined. *Gobionellus pseudofasciatus*, a new continental record, was collected in freshwater tributaries over sand substrate (Hastings, 1978; Gilmore and Hastings, in press). Many of the ophichthids were captured in reef rotenone collections (*Bascanichthys bascanium*, *Myrichthys oculatus)*, trawls and plankton nets (*Apterichthus kendalli*, *Callechelys muraena)*. *Ophichthus gomesi* has been

TABLE 1. Relative abundance and habitat distribution of new regional fish records from the Indian River lagoon and adjacent waters (depths less than 200 m). Habitat key: N = neritic; B = benthic-open shelf; R = offshore reefs; SR = surf zone reef; SS = surf zone-sand/shell bottom; I = inlets; GF = grass-flats; MAN = mangroves; SB = open sand bottom; LR = lagoon reefs; CRM = canal and river mouths; FTC = freshwater tributaries and canals. Fish abundance categories (Starck, 1968): U = undetermined; R = rare; O = occasional; F = frequent; C = common; A = abundant. Format of Tables 1 and 2 follows Gilmore (1977). The museum in which voucher specimens are deposited is designated as: IRCZM = Indian River Coastal Zone Museum; UCF = University of Central Florida; UF = University of Florida; FMNH = Field Museum of Natural History; USNM = U.S. National Museum.

SPECIES	MUSEUM	N	B	R	SR	SS	I	GF	MAN	SB	LR	CRM	FTC
Lamnidae													
Isurus paucus	IRCZM	O				R							
Carcharhinidae													
Carcharhinus signatus	IRCZM	O											
Prionace glauca	IRCZM (photos)	O				R							
Acipenseridae													
Acipenser oxyrhynchus	IRCZM	O				O							
Muraenidae													
Enchelycore carychroa	USNM			U									
Gymnothorax hubbsi	USNM		U	U									
Muraena robusta	UF			U									
Congridae													
Conger oceanicus	UCF		U										
Ophichthidae													
Apterichthus kendalli	IRCZM		U										
Bascanichthys bascanium	IRCZM			U			U						
Callechelys muraena	IRCZM		U										
Ichthyapus ophioneus	IRCZM		U										
Myrichthys oculatus	IRCZM			O			O						
Ophichthus gomesi	IRCZM		U					O		U			
Esocidae													
Esox americanus	IRCZM												O
Synodontidae													
Saurida brasiliensis	IRCZM		O										
Synodus synodus	IRCZM			O									

SPECIES	MUSEUM	N	B	R	SR	SS	I	GF	MAN	SB	LR	CRM	FTC
Aphredoderidae													
Aphredoderus sayanus	IRCZM												
Batrachoididae													
Opsanus pardus	IRCZM			C									
Antennariidae													
Antennarius ocellatus	IRCZM			O									
Ogcocephalidae													
Ogcocephalus parvus	IRCZM		O										
Bregmacerotidae													
Bregmaceros atlanticus	IRCZM	U	U										
Gadidae													
**Physiculus fulvus*	IRCZM		O										
Poeciliidae													
Xiophophorus helleri (exotic)	IRCZM												
Holocentridae													
Corniger spinosus	IRCZM			O									
Holocentrus ascensionis	IRCZM			O									
Aulostomidae													
Aulostomus maculatus	IRCZM				R								
Syngnathidae													
Amphelikturus dendriticus	IRCZM	R											
Syngnathus elucens	IRCZM	R		R									
Scorpaenidae													
Scorpaena isthmensis	IRCZM		O	O									
Scorpaenodes tredecimspinosus	IRCZM		U										
Triglidae													
Peristedion miniatum	IRCZM		U										
Dactylopteridae													
Dactylopterus volitans	IRCZM	R											
Centropomidae													
Centropomus parallelus	UMML											U	U

SPECIES	MUSEUM	N	B	R	SR	SS	I	GF	MAN	SB	LR	CRM	FTC
Percichthyidae													
Morone saxatilis	IRCZM (photo)							R		R			
Synagrops bella	IRCZM			U									
Serranidae													
Anthias nicholsi	IRCZM			U									
Epinephelus cruentatus	IRCZM			R									
Epinephelus adscensionis	IRCZM			R									
E. flavolimbatus	IRCZM			U									
E. guttatus	IRCZM			U									
Holanthias martinicensis	IRCZM			A									
Schultzea beta	IRCZM			U									
Priacanthidae													
Priacanthus cruentatus	IRCZM			U									
Apogonidae													
Astropogon alutus	IRCZM			U									
A. puncticulatus	IRCZM							F					
A. stellatus	IRCZM						O	F					
Phaeoptyx xenus	IRCZM			U									
Branchiostegidae													
Caulolatilus microps	IRCZM		U										
Echeneidae													
Phtheirichthys lineatus	IRCZM	U											
Carangidae													
Seriola zonata	IRCZM	U											
Uraspis secunda	IRCZM	U											
Gerreidae													
Eucinostomus jonesi	IRCZM						U						
Sparidae													
Calamus leucosteus	IRCZM	U											
C. penna	IRCZM	U											
Pagrus pagrus	IRCZM	O	C	C									
Sciaenidae													
Equetus sp. nov. ("Bar drum")	IRCZM		C										

SPECIES	MUSEUM	N	B	R	SR	SS	I	GF	MAN	SB	LR	CRM	FTC
Cichlidae (all exotics)													
Cichlasoma octofasciatum	IRCZM												F
Tilapia mariae	IRCZM												U
T. melanotheron	IRCZM							U		U		U	U
Pomacentridae													
Chromis insolatus	IRCZM			C									
C. scotti	IRCZM			C									
Labridae													
Hemipteronotus splendens	IRCZM			U									
Scaridae													
Sparisoma atomarium	IRCZM			U									
S. viride	IRCZM			F									
Mugilidae													
Mugil gaimardianus	IRCZM							U		U			
M. gyrans	IRCZM							U		U			
Opistognathidae													
Opistognathus aurifrons	IRCZM			F									
O. sp. nov.	UF			F			U			R			
Clinidae													
Chaenopsis limbaughi	IRCZM			U									
Emblemaria pandionis	IRCZM			U									
Labrisomus haitiensis	IRCZM			U									
Stathomonotus hemphilli	IRCZM			U									
Blenniidae													
Hypleurochilus springeri	IRCZM			U									
Hypsoblennius hentzi	IRCZM			U			U						
Callionymidae													
Callionymus bairdi	IRCZM			U									
Gobiidae													
Coryphopterus personatus	IRCZM			F									
C. punctipectophorus	IRCZM			U									
Gobionellus pseudofasciatus	IRCZM												F
G. saepepallens	IRCZM		U										

SPECIES	MUSEUM	N	B	R	SR	SS	I	GF	MAN	SB	LR	CRM	FTC
Ioglossus calliurus	IRCZM			R									
Lythrypnus spilus	IRCZM			F									
Microgobius carri	IRCZM		F										
Nes longus	IRCZM			U									
**Psilotris* sp.	IRCZM			U									
Varicus marilynae	USNM		U										
Gempylidae													
Gempylus serpens	IRCZM	U											
Lepidocybium flavobrunneum	IRCZM	O											
Promethichthys prometheus	IRCZM	U											
Ruvettus pretiosus	IRCZM	O											
Scombridae													
Sarda sarda	IRCZM	O											
Istiophoridae													
Tetrapterus pfluegeri	IRCZM (photo)	R											
Bothidae													
Citharichthys cornutus	IRCZM		U										
C. gymnorhinus	IRCZM		C										
Paralichthys oblonga	IRCZM		U										
Triacanthodidae													
Hollardia meadi	FMNH		U										
Monacanthidae													
Aluterus monoceros	IRCZM	U											
Molidae													
Mola lanceolata	IRCZM	R											
TOTAL BY HABITAT		22	22	44	1	3	5	8	0	6	0	2	8
TOTAL NEW RECORDS 98													

*Species not recorded in Robins et al., 1980.

recently recorded from the Indian River lagoon by Snelson (1981). Also collected from shallow reef formations were new records of certain opistognathids, clinids, chaenopsids, blenniids, a callionymid and several apogonids. One of the opistognathids represents an undescribed species (*Opistognathus* sp. nov., Smith-Vaniz, pers. comm.).

Two additional anguilliform species *Conger oceanicus* (Congridae; Franklin Snelson, pers. comm.) and *Muraena robusta* (Muraenidae, Böhlke and Ross, 1981) have been added to the list from captures made on the continental shelf SSE and E of Ponce de Leon inlet. Another record from the literature is that of *Hollardia meadi* (Triacanthodidae) recorded by Tyler (1970) from Oregon sta. 5190 taken east of Melbourne, 28°07'N, 80°03'W, (55-59 m depth).

New shark records (i.e., *Isurus paucus*, *Carcharhinus signatus* and *Prionace glauca)* came from inshore, sublittoral captures by surf fishermen (Dodrill, 1977; Dodrill and Gilmore, 1979). As all of these species are normally considered pelagic; the capture of specimens in sublittoral neritic locations is unusual. The *I. paucus* record was a new continental record for this species (Dodrill and Gilmore, 1979). The senior author has subsequently examined 13 specimens caught in the swordfish *(Xiphias gladius)* fishery operating in the Florida Current off east-central Florida. Most gempylids also came from shelf edge captures incidental to the swordfish catch as did *Tetrapterus pfluegeri* and *Mola lanceolata*.

Captures of new regional records from the Indian River lagoon are limited to *Morone saxatilis*, *Astropogon puncticulatus*, *A. stellatus*, *Eucinostomus jonesi*, *Mugil gaimardianus* and *M. gyrans*.

Fresh and brackish water collections provided specimens of *Esox americanus*, *Aphredoderus sayanus*, *Centropomus parallelus* and the exotic species *Xiphophorus helleri*, *Cichlasoma octofasciatum*, *Tilapia mariae* (Clark, 1981) and *T. melanotheron*. *Tilapia melanotheron* is occasionally caught in the gill net mullet fishery in the Banana River and/or Newfound Harbor portions of the Indian River lagoon estuarine system.

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David Nickerson of the Florida Department of Natural Resources is responsible for the capture and identification of *Mugil gaimardianus* and *M. gyrans*. Mark Leiby also of FDNR, identified ophichthid leptocephali recognized as new records. Walter Courtenay and Dan Hensley verified identification of all exotic species. Tom Fraser collected and identified specimens of *Centropomus parallelus* from the St. Lucie River and commented on the familial placements of *Synagrops bella*. William Anderson confirmed anthiid identification and William Smith-Vaniz identified the new opistognathid. Carter Gilbert and George Burgess of the Florida State Museum also confirmed various identifications.

Robert S. Jones made helpful comments on an early draft of this manuscript and collected specimens on lockout dives from JOHNSON-SEA-LINK submersible. Franklin F. Snelson, Jr. made helpful comments on the manuscript and informed us of the new record of *Conger oceanicus*.

Biologists responsible for aid in the capture and in some cases, the identification of specimens for both Applied Biology, Inc. and the Harbor Branch Foundation, Inc. are Bruce Peery, Allen

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OBSERVATIONS ON THE ECOLOGY AND DISTRIBUTION OF CERTAIN TROPICAL PERIPHERAL FISHES IN FLORIDA

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Abstract: *Maximum densities of east-central Florida populations of the tropical peripheral fishes,* Oostethus brachyurus lineatus, Gobiomorus dormitor, Awaous tajasica *and* Gobionellus pseudofasciatus *occurred during the winter and spring months in the lower portions of freshwater tributaries to the Indian River lagoon. All populations declined during the wet season, reaching minimum levels during peak rainfall periods. Specific microhabitat requirements were observed for each species. These species have a limited Florida range which is discussed relative to various environmental parameters and dispersal mechanisms, such as water temperature regimes, oceanic current patterns and particular microhabitat preferences.*

The freshwater fish fauna of peninsular Florida has no indigenous primary freshwater representatives of tropical American origin. Floridian primary freshwater fishes have been recruited from temperate North American families (i.e., Centrarchidae, Percidae, Catostomidae and Cyprinidae; Carr and Goin, 1955; Briggs, 1958) and comprise 29-46% of the freshwater fish fauna depending on the latitude along the Florida peninsula. Therefore, approximately 54-71% of the fishes occurring in the fresh waters of peninsular Florida may be classified as secondary freshwater or euryhaline marine forms (Kushlan and Lodge, 1975; Gilmore, 1977a). Marine fishes occurring in fresh water have been known collectively as peripheral species ("diadromous", "vicarious", "complementary" or "sporadic" forms after Meyers, 1951). In Florida, many of these peripheral species are of tropical origin.

Four tropical peripheral species, the opposum pipefish, *Oostethus brachyurus lineatus* (Kaup), river goby, *Awaous tajasica* (Lichtenstein), slashcheek goby, *Gobionellus pseudofasciatus* Gilbert and Randall, and the bigmouth sleeper, *Gobiomorus dormitor* Lacépède, have been considered rare in Florida waters and have received little study (Gilmore, 1977b; Gilbert, 1978; Hastings, 1978). Recent collections of these species have produced enough information for a preliminary analysis of the temporal and spatial distribution of east-central Florida populations. These peripheral tropical species are exceptional in being among the few examples of euryhaline tropical freshwater species (either "vicarious", "diadromous" or "complementary") occurring in the fresh waters of continental North America. In contrast, the continental North American marine ichthyofauna contains numerous examples of tropical Caribbean marine forms.

METHODS — Specimens were captured utilizing a variety of techniques (Gilmore, 1977a). Collections were made from November 1971 to December 1980 in a wide variety of neritic, estuarine and freshwater habitats from 26°58'N to 29°05'N along the Florida east coast (Fig. 1; Gilmore, 1977a; Gilmore, 1977b; Hastings, 1978).

All fish length measurements are standard lengths (SL) unless otherwise noted.

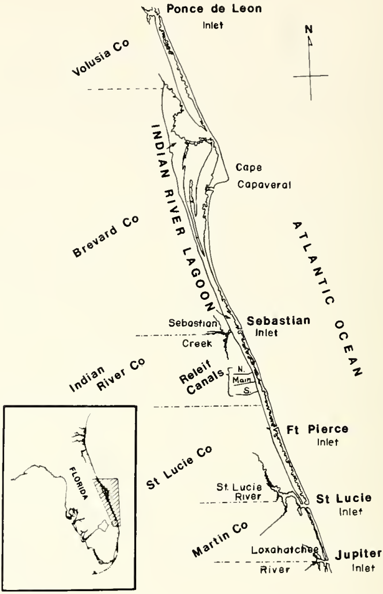

FIG. 1. Indian River lagoon of east central Florida and associated freshwater tributaries.

DISTRIBUTION AND NATURAL HISTORY OBSERVATIONS — Most specimens of the species discussed below were collected in low gradient freshwater rivers, creeks and canals flowing into the Indian River lagoon in east-central Florida. These freshwater tributaries have floodgates, salinity barriers or locks at various locations along their course. In all cases except one (*O. brachyurus*), the species discussed were collected from the downstream side of an artificial barrier. Additional captures of juvenile *Oostethus brachyurus* were made in saline estuarine waters and nearshore neritic waters.

Oostethus brachyurus lineatus (Kaup)
(Opossum Pipefish)

Distribution: (Fig. 2A, 3) *Oostethus brachyurus* (Bleeker) is widely distributed in tropical regions, occurring in the Atlantic, Indian and Pacific oceans (Dawson, 1979). The western Atlantic subspecies *O. brachyurus*

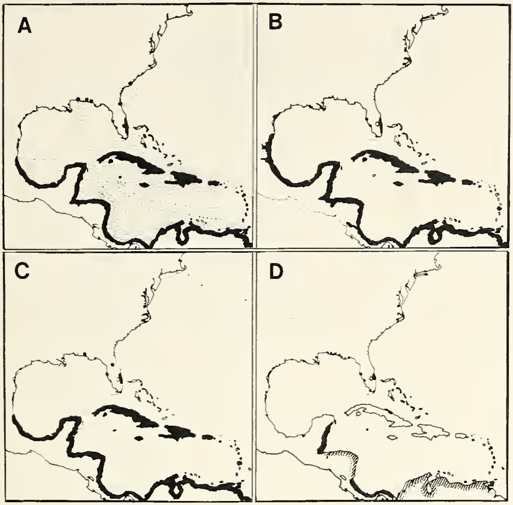

FIG. 2. Caribbean-Western Atlantic distribution of (A) *Oostethus brachyurus lineatus* (hypothetical oceanic distribution is stippled); (B) *Gobiomorus dormitor*; (C) *Awaous tajasica*; (D) *Gobionellus pseudofasciatus* (hypothetical continental distribution of *G. pseudofasciatus* is hatched).

lineatus occurs from South Carolina to São Paulo, Brazil and commonly enters fresh water in Central America, the Greater Antilles (Black and Montego rivers, Jamaica, Caldwell, 1966; Rio San Juan, Cuba, Eigenmann, 1902) and east-central Florida (Gilmore, 1977b). It has not been collected from freshwater tributaries in extreme southern Florida (vicinity of Florida Bay), western Florida or the northern Gulf of Mexico. Extralimital (i.e., beyond the normal geographic range of breeding populations) salt marsh captures have been made in Mississippi, but these populations did not overwinter (Dawson, 1970). One individual was collected in *Sargassum* in the northeastern Gulf of Mexico (Hastings and Bortone, 1976). Darnell (1955a, 1962) did not take this species in the Rio Tamesi drainage in northeastern Mexico. However, Jordan and Dickerson (1908) record 3 specimens of *O. brachyurus* (1 female, 2 males, as *Doryhamphus lineatus)* from lagoons at Tampico, Tamaulipas, Mexico. It is possible that permanent breeding populations may occur in fresh waters of this region of Mexico (22°10'N), but this has not been documented. Specimens have been collected recently from the lower reaches of the Rio Grande River on the Texas-Mexican border (Frank Pezold, pers. comm.).

Ecology: Between 1972 and 1981 235 specimens (64-175 mm SL) of the opossum pipefish were captured from all months of the year. Specimens

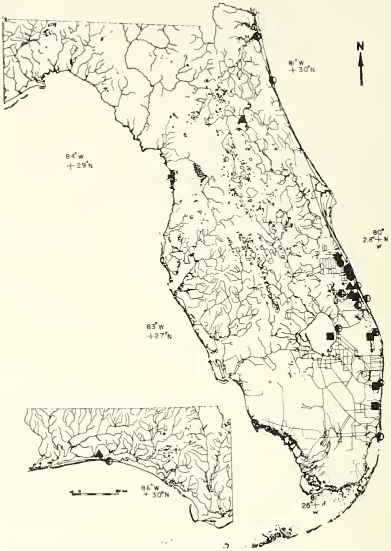

FIG. 3. Florida collection locations for *Oostethus brachyurus lineatus*, (◐); *Gobiomorus dormitor* (■); *Awaous tajasica* (▲); and all 3 species combined with *Gobionellus pseudofasciatus* (●).

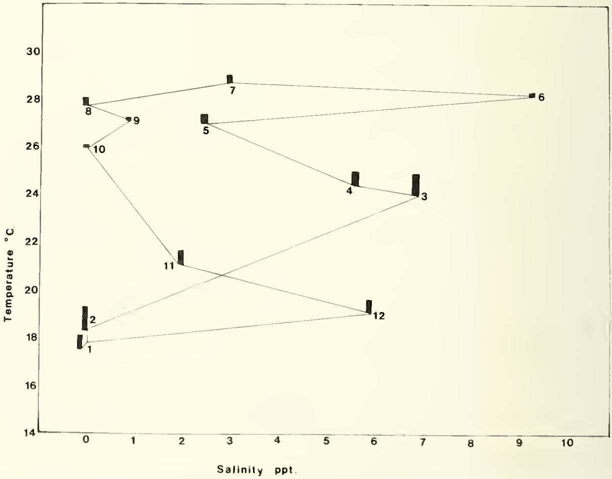

FIG. 4. Temperature-salinity hydroclimograph for *O. lineatus* using monthly means for collections made from 1972 to 1981. Dark bars are proportional to the total number of individuals collected during that month.

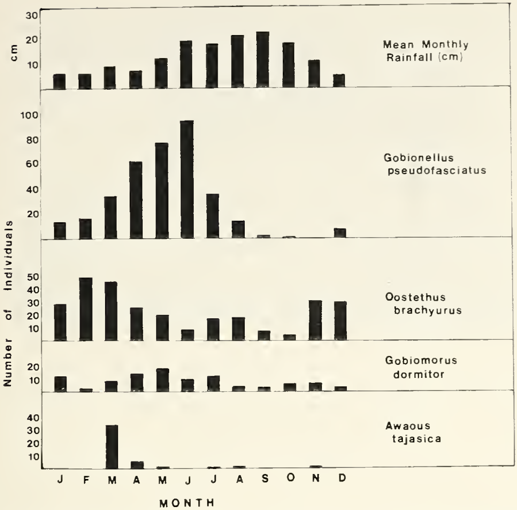

FIG. 5. Comparative numerical seasonal distribution of total monthly collections of *G. pseudofasciatus*, *O. brachyurus*, *G. dormitor* and *A. tajasica* with mean monthly rainfall (65 yr. mean from Fellsmere Station 7 SSW, Indian River Co., NOAA Climatological Data, Annual Summary, Florida, 1977).

were collected from the St. Lucie River (Martin Co.), and Sebastian Creek drainages, and the North, Main and South Relief canals in Indian River County, Florida. Specimens from the Indian River lagoon were collected at 2 seagrass bed locations in northern St. Lucie County. Salinities at the time of capture ranged from 0.0-37.0 ppt, though most specimens, 98%, came from fresh water (<1.0 ppt). Water temperatures at capture ranged from 15.0 (at 0.0 ppt) to 30.5°C (at 0.0 ppt). A climagraph (Fig. 4) shows mean salinity and temperature values for monthly collections of opossum pipefish and the estuarine and neritic occurrence of juveniles during March and June. Up to 25 individuals were taken in a single collection (Nov. 1979) with 145 individuals, 64% of all captured, collected during the winter months, November through March (Figs. 4 and 5). Few specimens were collected during the wet season, June through October, with a seasonal population low during the peak rainfall months of August, September and October (Figs. 4 and 5).

The smallest specimens (five, 64-86.3 mm SL) were taken at higher salinities (maximum of 37 ppt) in seagrass beds of the Indian River lagoon and in neritic waters of the Atlantic Ocean. These specimens were considered juveniles, as pouch development normally takes place at lengths greater than 100 mm.

Our observations indicate that *O. brachyurus* does not breed in neritic or pelagic waters, but is anadromous. Suitable biotopes for breeding are apparently limited as this species has been found breeding throughout the year only in tropical America, the Antilles, and in east-central Florida. To-date, the only permanent breeding population reported north of Mexico occurs in patches of the emergent aquatic plants *Polygonum hydropiperiodes* and *Panicum* spp. in freshwater tributaries to the Indian River lagoon (Christensen, 1965; Gilmore, 1977b). Extralimital captures of *O. brachyurus* in breeding condition have been made at the mouth of the St. Johns River, Florida (McLane, 1955), and from coastal South Carolina (Fowler, 1945, 2 specimens, 1 a male with eggs). Hildebrand (1939) indicated that a permanent breeding population occurs in Gatun Lake, Panama, and Gilbert and Kelso (1971) provided evidence that this species breeds in tributaries to the Tortuguero estuary, Caribbean Costa Rica.

Gobiomorus dormitor Lacépède
(Bigmouth Sleeper)

Distribution: (Figs. 2B, 3) *Gobiomorus dormitor* occurs from the Aransas River, Texas and east-central Florida to Surinam (Miller, 1959; Briggs, 1958; Gilmore, 1977; Hoese and Moore, 1977). The bigmouth sleeper is common in the Rio Grande and in the Rio Tamesi drainage in Mexico (Darnell, 1955a, 1962; Hoese and Moore, 1977) south through Central America (Nordlie, 1979, 1981) and in Jamaica (White River, Caldwell, 1966), Cuba (Poey, 1866; Eigenmann, 1902, Rio San Juan and Vento Springs), Puerto Rico (abundant, Rio Loiza, Rio de Caguitas, Rio Bayamon, Evermann and Marsh, 1900), and Martinique in the Lesser Antilles (Schultz, 1949).

Current fish surveys suggest a limited Florida distribution as *Gobiomorus dormitor* has not been collected from freshwater tributaries of Florida Bay and the Gulf of Mexico (Tabb and Manning, 1961; Gunter and Hall, 1965; Odum and Heald, 1971; Barnett, 1972; Kushlan and Lodge, 1974; Brockmann, 1974). It has not been recorded from the Bahama Islands (Böhlke and Chaplin, 1968) nor from tributaries of the northern or northeastern Gulf of Mexico (Bailey et al., 1954; Hellier, 1967; Yerger, 1977).

Ecology: Ninety-one specimens of the bigmouth sleeper (16-317 mm SL) have been collected in freshwater tributaries to the Indian River lagoon (South and North Relief canals, Indian River County, and Sebastian Creek, Indian River and Brevard counties) in salinities of 0.0-13.0 ppt and at temperatures of 10.5-29.5°C. Two specimens were collected at temperatures as low as 10.5°C. However, most individuals were captured from March to July at mean temperatures above 22°C (Fig. 7).

Specimens were collected during all months of the year but were most common from January through July, with the largest single collections occurring in January and July. Like *O. brachyurus*, *G. dormitor* experienced a

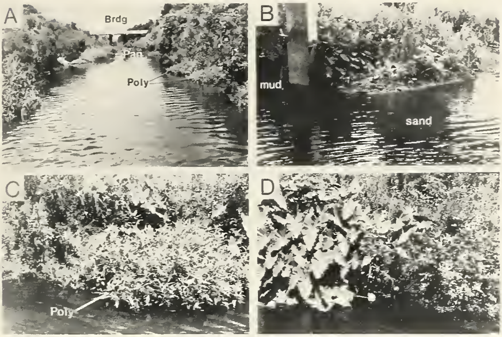

FIG. 6. (A) South Relief Canal at S.R. 605 bridge, Indian River County. *Awaous tajasica* was captured under the bridge, *O. brachyurus* in *Polygonum hydropiperoides* (Poly) and *Panicum purpurascens* (Pan). (B) North Relief Canal under U.S. Hwy 1 bridge where largest collections of *A. tajasica* have been made (mud and sand) along with *Gobionellus pseudofasciatus* (sand). (C) *Polygonum hydropiperoides*, the principal microhabitat of *O. lineatus*. (D) Deep undercut bank, a typical *Gobiomorus dormitor* microhabitat.

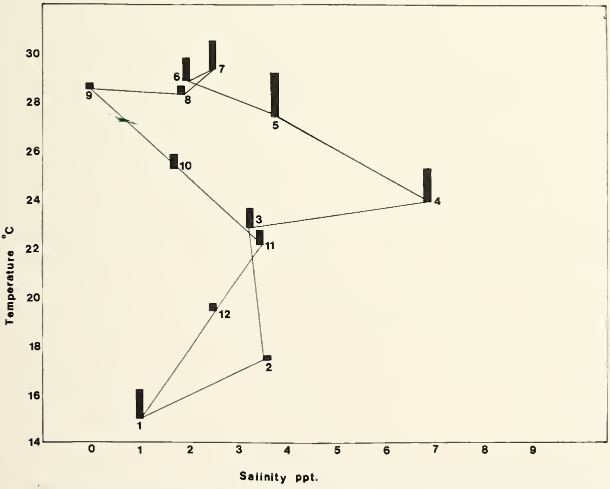

FIG. 7. Temperature-salinity hydroclimograph for *G. dormitor* using monthly means for collections made from 1972 to 1981. Dark bars are proportional to the total number of individuals collected during that month.

population decline during the peak wet season months, August through October (Figs. 5 and 7). Juveniles were most common in late fall and spring collections.

Most large adults were collected near stream banks by hand, hook-and-line, seine and with gill nets. Juveniles (16-50 mm) were collected over sand bottoms and along heavily vegetated shallow shorelines (Fig. 6). No specimens were taken in extensive, higher-salinity (17-40 ppt) collections made along mangrove shorelines and in marshes, seagrass beds, open sand bottoms and lagoon reefs within the Indian River lagoon (Gilmore, 1977a). East-central Florida populations of *G. dormitor* were found throughout the year only in freshwater tributaries, canals and natural stream beds.

Our studies and the observations of others (e.g., Darnell, 1962; Nordlie, 1981) show the biotope preference of *Gobiomorus* to be quiet silt or sand bottoms in relatively shallow waters near vegetated banks of sluggish streams. All tributaries in which we collected this species have a relatively low gradient with currents varying from 0.2-1.0 m/sec. However, currents may increase temporarily (to 1.6 m/sec) when floodgates are opened, particularly in small canals. The benthic solitary, semi-burrowing nature of adult *G. dormitor* was verified by our collections. Juveniles (16-40 mm SL) were observed in groups of 4 to 5 individuals loosely dispersed, resting on a sand bottom and occasionally rising into the water column. Our collections do not show a preference for upstream or downstream locations within the freshwater tributary as *G. dormitor* has been collected at all stream collection sites and upstream as far as dam or floodgate barriers. However, it has not been collected from tributary mouths, or from the Indian River lagoon. The periodically opened locks on the St. Lucie River may allow the fish to pass further upstream as *G. dormitor* has been collected in Lake Okeechobee (Lee et al., 1980). Some lacustrine biotope preferences appear to be quite different than preferred stream habitats (e.g., rock bottom to depths below 15 m in Lake Jiloa, Nicaragua) and reveal the opportunistic and adaptive nature of this species (McKaye et al., 1979; Nordlie, 1981).

Although *G. dormitor* appears to prefer epibenthic locations and stream banks during diurnal periods, there are several nocturnal observations indicating that the species migrates to the surface, and occasionally out of the water (semiterrestrial activity) along stream banks. Christensen (1965) observed . . . "15 to 20 individuals among rocks . . . at night . . . in water less than 4 inches deep" below a floodgate in the Loxahatchee River, Palm Beach County, Florida. Darnell (1955a, 1955b) observed nocturnal semiterrestrial activity in the Rio Tamesi and Rio Sabinas, Tamaulipas, Mexico, and Koenig, et al., (*in* Thorson, 1976) described *G. dormitor* as ". . . often seen at night at the surface of shallow waters . . ." in Lake Nicaragua.

The bigmouth sleeper has been found to prey upon crustaceans, fishes, various insects and arachnids (Meek and Hildebrand, 1916; Darnell, 1965; Zaret and Rand, 1971; Nordlie, 1981). The species is a strict carnivore whose maximum size (610 mm SL; Hoese and Moore, 1977) allows it to be considered a top predator in many freshwater habitats. Loftin (1965) considered it to be one of the "dominant large predators in most of the freshwater streams of Panama".

Darnell (1962) reported that *G. dormitor* may be somewhat "catadromous", spawning downstream in "brackish-water lagoons and estuaries". Large sexually mature adults and the smallest individuals (to 21 mm) were collected in the lower estuary at Tortuguero (Nordlie, 1981; Costa Rica), therefore, indicating downstream spawning activity. However, observations of reproduction in freshwater Lago de Yojoa in Honduras (Darnell, 1962) and Lake Jiloa, Nicaragua (McKaye et al., 1979) demonstrate that estuarine migrations are not necessary for effective reproduction in this species. In our collections the youngest specimens (16-23.5 mm) occurred in fresh to brackish water on the downstream side of salinity barriers, at salinities of 0.0-13.0 ppt. Insufficient specimens have been captured to allow isolation of specific spawning locations, but the capture of young-of-year as well as the capture of a ripe female in Sebastian Creek indicates that this species apparently spawns within this tributary.

Awaous tajasica (Lichenstein)
(River Goby)

Distribution: (Figs. 2C, 3). *Awaous tajasica* ranges from Florida south to Cuba (Poey, 1866; Rio Cuyaguateje, Eigenmann, 1902; Yerger, 1978), Puerto Rico (Bayamon River, Rio de Caguitos, Evermann, 1899; Anasco River, Austin, 1971), Jamaica (Port Antonio, Caldwell, 1966), Costa Rica (Gilbert and Kelso, 1971), Panama (Brockmann, 1965), Venezuela (Schultz, 1949) and Brazil (Brockmann, 1965). *Awaous tajasica* has not been recorded from the Lesser Antilles, Bahama Islands where major freshwater drainages are absent (Böhlke and Chaplin, 1968) or from the drainages of the western Gulf of Mexico (Darnell, 1955a, 1962; Hoese and Moore, 1978). The only North American records for this species are from Florida. Currently the only documented occurrence of *A. tajasica* in peninsular Florida is from captures made in the Oklawaha-St. Johns drainage (McLane, 1955) and tributaries to the Indian River lagoon (Gilmore, 1977a, b; Yerger, *in* Gilbert, 1978). This species was also collected from Garnier's Creek, a tributary to Choctawhatchee Bay in the panhandle region of west Florida (Yerger, *in* Gilbert, 1978). However, the permanency of a northwest Florida population at this latitude (30°30'N) is unknown. *Awaous tajasica* has not been recorded from fresh or marine waters south of the St. Lucie River, Martin County (27°10'N) and was not listed by Kushlan and Lodge (1974) as a member of the south Florida ichthyofauna.

Ecology: Forty-three specimens (29.5-148.0 mm SL) of the river goby have been collected from the St. Lucie River (Martin County), North and South Relief canals (Indian River County) and the N. Fork of Sebastian Creek (Brevard County). No specimens were collected at tributary mouths or in the Indian River lagoon itself. Salinities and temperatures at capture varied from 0.0-4.0 ppt and from 20-28°C, respectively, with most specimens coming from freshwater. Specimens were collected from March to November, with most from March through May. The largest single collection was made in March 1979 when 32 individuals (29.5-75.2 mm SL) were captured on a sand bottom under the U.S. Route 1 bridge over the North Relief Canal. Ninety-six percent of the captures have occurred on open sand bottoms below bridges (Fig. 6) which may indicate an association with shaded portions of the stream and/or sediment deposited around bridg pilings. Both maximum numbers and the smallest individuals occur i March, indicating an early spring recruitment. This species has been ob served to burrow into sand bottoms and may account for its disappearanc from winter seine samples.

The genus *Awaous* is represented by several species distribute throughout the world tropics (Brockmann, 1965). All occur in fresh water adults and little is known of their spawning habits and early life history. Th occurrence of larval and small juvenile *A. tajasica* in the mouths of estuari implies that early development takes place under brackish estuarine conditions and not in freshwater. Both Gilbert and Kelso (1971) and Schultz (1949) collected their smallest specimens (12.5-19 mm SL) from the mouths of estuaries in Costa Rica and Venezuela.

Central American specimens (adults and juveniles) have been collected in various shallow lotic freshwater habitats usually with no aquatic vegetation and over sand, mud or rocky bottoms (Loftin, 1965; Gilbert and Kelso, 1971). Loftin (1965) collected the species at altitudes up to 610 m above mean sea level along the Atlantic slope in Panama. Currents in the Panamanian streams collected by Loftin varied from “fast” to “slow” demonstrating that current flow rate was not a major barrier to the upstream migrations to higher elevations. As there are no records of lentic populations of *A. tajasica*, this species may prefer flowing water in lotic habitats, hence its limited distribution in Florida.

Gobionellus pseudofasciatus Gilbert and Randall
(Slashcheek Goby)

Distribution: (Figs. 2D, 3) the slashcheek goby, *Gobionellus pseudofasciatus*, may be considered a tropical continental species having been recorded from Trinidad, Panama, Costa Rica, Guatemala, Belize, east-central Florida, the Bahamas, Greater Antilles, and Lesser Antilles (Hastings, 1978). It has not been recorded in Florida south or north of tributaries to the Indian River lagoon nor from tributaries of the Gulf of Mexico.

Ecology: Three hundred and fifty specimens (17-44 mm SL) of *G. pseudofasciatus* were collected from the South Relief Canal and the Sebastian Creek drainage. Specimens were captured in shallow water, primarily over sand bottom throughout the year and at salinities and temperatures

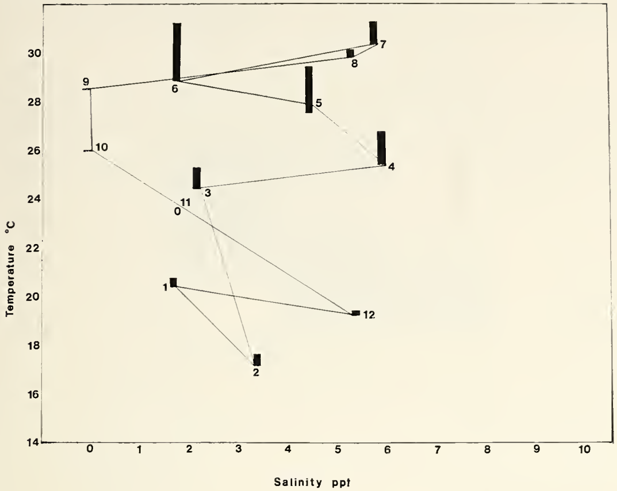

FIG. 8. Temperature-salinity hydroclimograph for *G. pseudofasciatus* using monthly means for collections made from 1972 to 1981. Dark bars are proportional to the total number of individuals collected during that month.

ranging from 0.0-13.0 ppt and 17.0-32.0°C, respectively. This species is most common during the spring dry season, increasing in numbers as water temperatures increase from March through June (Figs. 5, 8 and 9).

Stream populations were least abundant at our stations during the peak of the wet season from August through November. A comparison of upstream and downstream stations suggests that *G. pseudofasciatus* move into downstream localities during December and into upstream localities during January, reaching maximum numbers upstream from March through May (Fig. 9). Upstream populations decline from May through September while downstream populations increase during May and June, but then decline from July through August.

PHYSICAL PARAMETERS AND BIOGEOGRAPHY—The 4 species discussed exemplify a basically continental distribution limited to subtropical and tropical fresh waters, estuaries and nearshore neritic waters (Fig. 2). This basic distribution pattern is also seen in 54 other tropical fish species occurring in east-central Florida, most of which are estuarine or marine forms (Table 1). Many of these species have a Florida distribution limited to the coastline from the vicinity of Cape Canaveral and Sebastian Inlet south to Biscayne Bay. The following discussion considers several environmental variables which may create the conditions allowing *Oostethus brachyurus lineatus*, *Gobiomorus dormitor*, *Awaous tajasica* and *Gobiomorus* _pseudofasciatus_ and possibly other tropical species to be distributed as they are.

TABLE 1. Tropical marine fishes showing a disjunct Caribbean-east Florida distribution, that are common to abundant in the Indian River lagoon or adjacent continental shelf, i.e., not recorded or _rarely_ occurring on continental shelf of west Florida (Springer and Woodburn, 1960; Springer, 1961; Moe and Martin, 1965; Smith, 1976), northern Gulf of Mexico (Hastings, 1979), and Texas (Hoese and Moore, 1978). Fishes following this same distribution pattern but considered rare in east-central Florida have been omitted from this list.

Species
Engraulidae
Anchoa lamprotaenia
Synodontidae
Synodus saurus
Ophidiidae
_Lepophidium cervinum_*
Scorpaenidae
_Scorpaena grandicornis_*
Centropomidae
_Centropomus pectinatus_*_Eu_
Serranidae
Hypoplectrus gemma
Prontogrammus auerorubens
Grammistidae
_Rypticus bistrispinus_*
_R. saponaceus_*
Pomadasyidae
_Anisotremus surinamensis_*
_Haemulon parrai_*
_H. sciurus_*
Sparidae
_Archosargus rhomboidalis_*
_Diplodus argenteus_*
Sciaenidae
_Bairdiella sanctaeluciae_*
_Equetes acuminatus_*
_Umbrina coroides_*
Pempheridae
_Pempheris schomburgki_*
Labridae
_Halichoeres maculipinna_*
Scaridae
Scarus guacamaia
_Sparisoma chrysopterum_*
_S. rubripinne_*
Opistognathidae
_Opistognathus aurifrons_*
_O. robinsi_*
Dactyloscopidae
_Dactyloscopus crossotus_*
_Gillellus greyae_*
_G. rubrocinctus_*
Apogonidae
_Apogon binotatus_*
A. planifrons
_A. stellatus_*
Lutjanidae
_Lutjanus analis_*
_L. apodus_*
L. jocu
Gerreidae
_Diapterus auratus_*_Eu_
_Eucinostomus lefroyi_*
_E. melanopterus_*
_Gerres cinereus_*
Clinidae
_Labrisomus gobio_*
_L. nuchipinnis_*
_Malococtenus macropus_*
_M. triangulatus_*
_Paraclinus nigripinnis_*
Blenniidae
_Blennius cristatus_*
Hypleurochilus aequipinnis
Gobiidae
Gnatholepis thompsoni
_Gobionellus oceanicus_*
_G. stigmaturis_*
_Lophogobius cyprinoides_*_Eu_
Bothidae
Citharichthys arenaceus
_Monolene antillarum_*
_Paralichthys dentatus_*
_P. oblongus_*
Scophthalmus aquosus
Tetraondontidae
_Sphoeroides testudineus_*

* = form permanent breeding populations in east central Florida.
Eu = euryhaline tropical species.

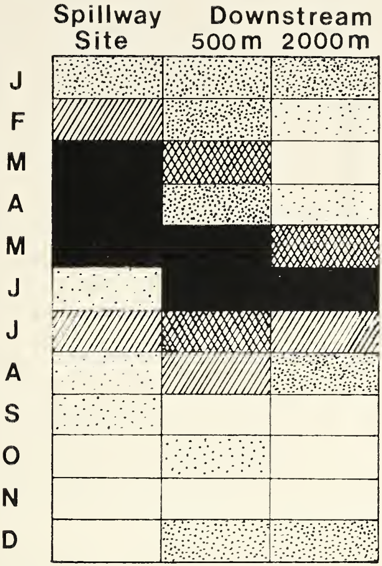

FIG. 9. Spatial and temporal distribution of *G. pseudofasciatus* in the north fork of Sebastian Creek and the Fellsmere Canal, 1979-1980. ☐ = 1-4 individuals, ░ = 5-10, ▨ = 11-15, ▩ = 16-19, ■ = 20+.

Temperature and Biogeography: Past and present temperature regimes have had a critical affect on the distribution of tropical species in the climatically transitional Florida peninsula. The presence of permanent breeding populations of tropical peripheral species in tributaries to the Indian River lagoon indicates that a survivable temperature regime occurs in these streams today. The minimum water temperature at which these fishes have been collected has ranged from 10.5°C for *Gobiomorus dormitor*, to 15°C for *O. brachyurus*, 17°C for *Gobionellus pseudofasciatus*, to 20°C for *A. tajasica*. The 10.5°C water temperature record for *G. dormitor* was exceptional as 9 previous years of winter temperature records from these streams reveal that temperature minima do not usually fall below 17°C. No hypothermal stress and mortality has been observed in these 4 species though it has been documented for other resident tropical species (Gilmore et al., 1978).

The range of local freshwater temperatures is not as great as the temperature range for local estuarine waters. Our data show a water temperature minimum in local freshwater streams 4-5°C higher than in the Indian River lagoon. Movement of shallow ground water through canal banks may account for some of these thermal differences (Beck, 1965). In Florida, winter freshwater temperatures are generally higher than those of adjacent estuarine waters because of isothermal spring and shallow groundwater sources. Isothermal spring effects on minimum water temperatures can be seen in various higher latitude tributaries such as the Suwannee River, 29°21 to 30°32′N latitude, with a minimum of 15°C (Beck, 1965), the Santa Fe River, 29°53′ to 29°55′N with 17°C (Hellier, 1967), and the Hillsborough River, 27°53′ to 28°21′N, with 19°C (Barnett, 1972). The use of these freshwater sources by fishes as refugia during periods of potential thermal stress has been documented (Gilmore et al., 1978).

The absence of the 4 species studied from freshwater tributaries elsewhere in peninsular Florida may be due to seasonally low neritic and estuarine water temperatures, particularly if the life history of these fishes includes a marine or estuarine phase (as seen in *O. brachyurus)*. Minimum marine and estuarine temperatures can be quite different between locations at the same latitude on the east and west coasts of peninsular Florida. The east central and southeast coasts of Florida are generally warmer (Fig. 10; Rivas, 1968; Clark et al., 1970; Ichiye et al., 1973; Gilmore et al., 1978).

Awaous tajasica, *O. brachyurus* and *G. pseudofasciatus* have not been recorded from fresh water in Florida south of 26°58′N. *Gobiomorus dor-*

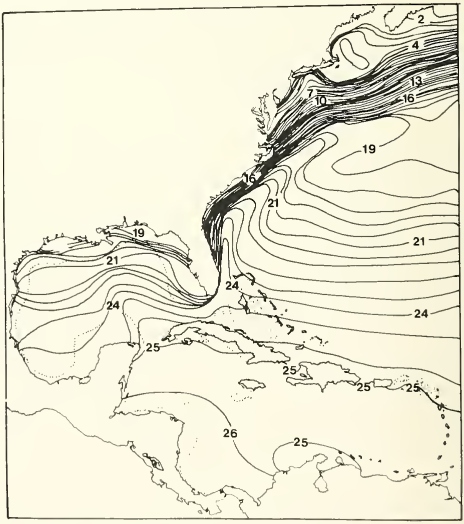

Fig. 10. Mean February sea surface temperatures for the western North Atlantic and Caribbean (redrawn from Fuglister, 1947, with conversion of original Fahrenheit temperatures to approximations of degrees Celsius).

mitor has been recorded from freshwater canals of southeast Florida in Palm Beach and Broward counties, south to 26°00'N (Herrema, 1974). As freshwater drainages of extreme southern Florida are seasonally warmer than those of the Indian River lagoon, temperature may not be the only major factor affecting the distribution of these fishes in extreme south Florida and southwest Florida.

Postglacial dispersal of tropical peripheral species from the Caribbean to Florida would be a plausible theory of distribution if water temperatures in Florida during the Wisconsin glaciation had been below the thermal tolerance levels of these species. Emiliani (1970) describes a 6°C water temperature oscillation for the Caribbean Sea between glacial and interglacial times. Our observations during the present interglacial period show water temperatures as low as 10.5°C at locations where these fishes were captured. The minimum water temperatures during the last glaciation were lower and possibly beyond the thermal tolerance levels of tropical peripheral species.

It is also possible that at least the gobioid tropical peripheral species are relicts of a more widespread interglacial distribution which included the northern Gulf of Mexico and southeastern Piedmont. A vicariant event (i.e., glaciation) could have then separated the Central American and Florida populations. A similar vicariance model for the distribution of Antillean-Central American tropical species to the Florida peninsula has been presented by Rosen (1975) for other organisms (e.g., Wagner's mastiff bat, *Eumops glaucinus floridanus*). The continental distribution of the fishes of the freshwater poeciliid genus *Heterandria* follow the generalized "North American-Caribbean track" described by Rosen (1975) with Florida and Central American forms representing 2 distinct species. *Heterandria* has a discontinuous generic distribution pattern demonstrating possible allopatric speciation (vicariance). The *Heterandria* distribution pattern is similar to that of the tropical peripheral fish species discussed here (excluding the Antilles and northern coast of South America).

Florida fish relicts may have survived the last glaciation through warm isothermal spring refugia. Temperature tolerance levels for these species may also have changed since the last glaciation and there are no available data on their present hypothermal tolerances. Behavioral adaptations such as burrowing (observed in *G. dormitor* and *A. tajasica)* and aestivation (not observed) during adverse environmental periods may have also enabled the gobioid species to survive glaciation. However, past and present water temperature regimes are but one of several environmental parameters affecting the present distribution of these species. This is demonstrated by their discontinuous distribution in warm water regions today.

Even if east Florida may have a relict tropical peripheral fish population, because of oceanic dispersal these populations may not have lost contact with southern populations. In contrast to the probable allopatric speciation in *Heterandria* varying degrees of taxonomic uniformity is found among these species throughout their range (Miller, 1959; Brockmann, 1965; Gilbert and Kelso, 1971; Gilbert and Randall, 1980). All western Atlantic populations of *O. brachyurus* show taxonomic continuity at the subspecific level as defined by Dawson (1979). This indicates gene flow rather than isolation and differentiation.

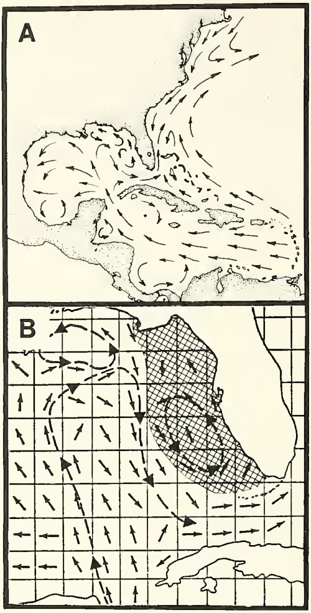

Fig. 11. (A) Tropical Western Atlantic current patterns during July (redrawn from Ichiye et al., 1973); (B) Loop Current and cross-hatched cyclonic gyre (cross-hatched region) on the west Florida continental shelf (redrawn from Ichiye et al., 1973).

Oceanic Currents and Biogeography: Oceanic currents are known to play an important role in the distribution of *O. brachyurus* (Dawson, 1979). *Oostethus brachyurus* has been captured at points of landfall for major warm water currents such as the Loop Current in the Gulf of Mexico and the Florida Current along the southeast coast of North America (Figs. 2A, 11 and 12). Juvenile *O. brachyurus* have been taken in neritic and pelagic collections (Gilbert and Kelso, 1971; Dawson, 1979) and have been found in association with floating *Sargassum* (Böhlke and Chaplin, 1968; Hastings and Bortone, 1976).

Oceanic dispersal may occur in the gobioid species as well as in *O. brachyurus* as all of these tropical peripheral species have demonstrated varying degrees of euryhalinity. At Tortuguero, Costa Rica, *A. tajasica* and

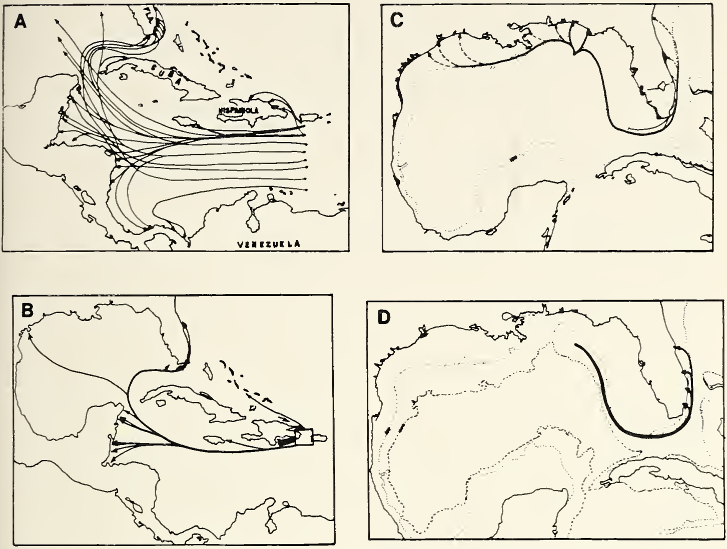

FIG. 12. (A) Drift card returns from a 24-27 October 1972 release in the Caribbean south of Puerto Rico (redrawn from Duncan et al., 1977, Fig. 2). (B) Drift bottle recovery sites after release in the Mona Passage west of Puerto Rico (redrawn from Metcalf et al., 1977, Fig. 2). (C) and (D) 2 studies of drift bottle trajectories after release from the northern portion of the Loop Current in the northern Gulf of Mexico (redrawn from Ichiye et al., 1973).

G. dormitor are found in the lower estuary and the former species was collected from the "tismiche" occurring in the inlet to Tortuguero Lagoon (Gilbert and Kelso, 1971). These observations and the occurrence of *A. tajasica* and *G. dormitor* in the Antilles suggests that these 2 species may also be subject to oceanic dispersal. There is no present evidence that *G. pseudofasciatus* may also be capable of oceanic distribution as it has only been recorded from continental locations and the continental island of Trinidad.

Oceanic distribution may be more plausible after the examination of the dispersal mechanism of tropical species geographically sympatric with these 4 tropical peripheral species. There are 54 marine and euryhaline estuarine fishes (Table 1) which have a discontinuous tropical distribution similar to the tropical peripheral species discussed here. Many of these 54 species have larvae capable of being carried by major oceanic currents.

Studies of drift bottle trajectories reveal potential drift routes for wafted juveniles of several tropical peripheral and marine species capable of oceanic transport by surface currents (e.g., *O. brachyurus*). Drift bottles released in the Gulf of Mexico near the apex of the Loop Current were carried to the

Florida east coast, not the Gulf coast of the Florida peninsula (Ichiye et al., 1973). Drift bottle movement to the central west coast of Florida was blocked by the presence of a cyclonic gyre located on the broad west Florida shelf (Figs. 11, 12). Once bottles reached the Florida Current they were carried by this strong and steady current to various locations along the Florida east coast. Drift bottle releases in the Caribbean (Duncan et al., 1977; Metcalf et al., 1977) also show a trajectory which, after passage through the Yucatan Straits (by the Yucatan Current) either end up in the western or northern Gulf of Mexico or east coast of Florida, not the west coast of peninsular Florida (Fig. 12). The lack of drift bottle returns from the west coast of peninsular Florida may provide an explanation for the absence of *O. brachyurus* records from that coast and possibly the absence of other tropical species (Table 1).

Oceanic current transit times may in part account for the discrepancy between the east and west Florida distribution of *O. brachyurus*. If peninsular west coast pipefish populations could be recruited from Central America via the Loop Current and associated gyres, transit time would be longer than for the east coast populations recruited from the more direct and swift Florida Current. Transit time in oceanic currents would be important if wafted individuals could only tolerate higher salinities for short periods of time. If the wafted individuals are small, in transit mortality rates resulting from predation could be very high.

HABITAT AND COMMUNITY RELATIONSHIPS—*Oostethus brachyurus*, *A. tajasica*, *G. dormitor* and *G. pseudofasciatus* have been collected together at various locations throughout the American tropics. The first 3 species have been collected at the same date and location in Venezuela (Schultz, 1949), Panama (Loftin, 1965), Costa Rica (Gilbert and Kelso, 1971) and Tampico, Mexico (Jordan and Dickerson, 1908). *Gobionellus pseudofasciatus* has been collected with the other species in Costa Rica (Gilbert and Kelso, 1971) and Belize (Thomerson and Greenfield, 1975, excluding *A. tajasica)*. However, observations in both Central America and east-central Florida show that although these species may be sympatric in various stream systems their specific biotope preferences are quite different. In Panama and Costa Rica adult *A. tajasica* were collected in flowing lotic water up to altitudes of 610 m and over sand, mud or rock bottoms (Loftin, 1965; Gilbert and Kelso, 1971), while *G. dormitor* was found in a variety of lotic and lentic habitats (Loftin, 1965; Gilbert and Kelso, 1971; McKaye et al., 1979; Nordlie, 1981). In east-central Florida adult *G. dormitor* were collected near stream banks and under bank overhangs with no apparent preference for floral types. Juvenile *G. dormitor* were observed on sandy bottoms near the bank adjacent to emergent or floating vegetation; they may hover above the sand or in the vegetation, but are most often seen resting on the bottom. Florida populations of *A. tajasica* occurred on shaded sand to mud bottoms and principally under bridges. East-central Florida freshwater collections of *O. brachyurus* were limited to emergent bank vegetation, specifically

Polygonum hydropiperiodes, *Panicum repens* and *P. purpurascens*. *Gobionellus pseudofasciatus* was captured on shallow open sand bottoms with little or no vegetative cover. These biotopes, including the specific floral species, are found in streams throughout peninsular Florida. This indicates that other environmental conditions are required by these particular species in addition to specific substrata.

Stream hydrography, water chemistry and biological parameters such as food resources (e.g., invertebrate fauna and microflora) and predators may vary considerable around the Florida peninsula (Beck, 1965). These factors may also play a vital role in the successful habitation of tropical peripheral fishes in east Florida streams. None of these parameters has been adequately studied relative to these species.

The study of faunas occurring within the same biotope and their interactions with tropical peripheral fish species may expose other mechanisms influencing the restricted Florida distribution of *O. brachyurus*, *G. dormitor*, *A. tajasica* and *G. pseudofasciatus*. These interactions may be both competitive and predatory, particularly for larvae and juveniles. Controlled experimental and *in situ* field observations of interspecific interactions may reveal biological factors affecting the distribution of these species.

In Florida, a study of freshwater and peripheral faunal interactions is complicated by the erection of artificial water flow barriers on most streams, canals and rivers in coastal regions of the lower peninsula south of 28°00'N. Many of these barriers do not permit peripheral tropicals to migrate into inland streams where potential interactions with primary freshwater fish faunas may occur. Primary freshwater faunas and communities in turn, are best developed and most diverse on the upstream side of these barriers where these tropical peripheral species do not occur.

The data presented in this study are coincidental to major faunal studies of freshwater fish communities in east-central Florida. Further analysis of these data and that of sympatric fishes will reveal additional biological information on these particular tropical peripheral species and their interspecific interactions within the freshwater fish community.

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RECOVERY AND PREVALENCE OF AEROMONAS HYDROPHILA IN 25 FLORIDA LAKES

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Abstract: *The abundance and distribution of* A. hydrophila *were measured in 25 lakes in the Central and North-Central Florida area. Verification of isolated* A. hydrophila *colonies was done using the* Aeromonas hydrophila *(AH) medium. Density of* A. hydrophila *ranged from 3-12,000 org/100 ml and appeared to increase as the trophic status of the lake changed from oligotrophic to eutrophic. However, no statistical correlation between trophic status and* A. hydrophila *density was attempted. Lake temperature and pH had no apparent effect on the recovery of* A. hydrophila *from Florida lakes.*

Aeromonas hydrophila is a facultative anaerobic, nonspore forming, oxidase-positive, flagellated Gram-negative aquatic bacterium. It is pathogenic to fresh water fish, turtles and alligators (DeFigueriedo and Plumb, 1977; Shotts et al., 1972). The organism is an opportunistic pathogen, affecting the potential host while under stress by physical factors resulting from eutrophication, low dissolved oxygen and/or abrupt temperature changes in the environment. In fish, the infection is commonly called "red sore disease" and results in a scale erosion and sloughing, purulent lesions and bleeding of the fins leading to septicemia and death (Rosner, 1964). Recent literature indicates that *A. hydrophila* is a primary human pathogen of serious consequences. Annapurna and Sangal (1977) reported that 50 isolates of *A. hydrophila* were potentially enteropathogenic. In normal individuals, *A. hydrophila* infections are usually self-limiting and remain localized; infections of skin, soft tissue, muscle and bone can occur. It has also been shown to be responsible for endocarditis (Davis et al., 1978; Rosner, 1964). The source of infection in most cases is directly associated with traumatic exposure to water or soil (Davis et al., 1978; Von Graevenitz, 1977; Von Graevenitz and Mensch, 1968). Infection through wounds or other skin abrasions is of particular significance with regard to swimming in Florida lakes.

Various studies have shown the cosmopolitan distribution of this organism in freshwater environments in the continental United States and Puerto Rico (Fliermans et al., 1977; Hazen and Fliermans, 1979; Hazen et al., 1978; Rippey and Cabelli, 1980; Siedler et al., 1980). Hazen et al. (1978) measured the abundance of *A. hydrophila* in 147 natural aquatic habitats in 30 states and Puerto Rico. They isolated viable organisms from all but 12 of the habitats studied. These studies revealed that this organism survives better in warm (20 C) than in cold waters. Florida is blessed with warm temperatures year round and is a state where water sports such as swimming, scuba diving and water skiing are prevalent. None of the previous studies on the ecology of *A. hydrophila* included any lakes from Florida. Therefore, the present study was designed to evaluate the media available for the recovery of this organism and the prevalence of *A. hydrophila* in 25 natural aquatic habitats in Central and North-Central Florida lakes. Test suspensions of *A. hydrophila* were used to assess the accuracy of the mA method (Rippey and Cabelli; 1979), Rimler-Shotts (RS) method (Shotts and Rimler, 1973), and the Peptone Beef Extract Glycogen agar (PBGA) method (McCoy and Pilcher, 1974) in recovering the organism. The membrane filtration method using mA agar resulted in higher recoveries of *A. hydrophila* and was used in this study.

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MATERIAL AND METHODS—Water samples were collected during February from the littoral zone of each lake in sterile (121 C for 15 min) 100 ml glass sampling bottles. Two samples from different locations were obtained from each lake. The interval between collection and assay of the samples did not exceed 4 hr. Samples were filtered through a 0.45 mm-grid, 47 mm-dia membrane filter (Millipore Corp., Bedford, MA) and plated onto mA agar plates (Rippey and Cabelli, 1979). Sterile aseptic systems and Swinnex filter holders (Millipore Corp.) were used for filtration. Appropriate dilutions of each sample were made following Standard Methods (1975). Three replicate membrane filtrations on mA agar plates were incubated at 35 C for 20 hr. Typical *A. hydrophila* colonies are circular, convex, yellow and 1-3 mm in dia (Rippey and Cabelli, 1979).

Presumptive *A. hydrophila* colonies growing in mA plates were confirmed using the *Aeromonas hydrophila* (AH) medium (Kaper et al., 1979). If the mA plates contained 10 *A. hydrophila* colonies, all colonies were picked. However, if more than 100 colonies were present, the square root of the *A. hydrophila* colonies present were selected. The same procedure was followed for atypical colonies present in mA plates. Atypical colonies were further characterized by their reaction in AH medium (Kaper et al., 1979) and the descriptions found in *Bergey's Manual of Determinative Bacteriology* (1974).

Temperature (degree Celsius) was measured in situ and pH was measured at the laboratory with a Corning model 130 pH meter (Orion Research Incorporated, Cambridge, MA).

RESULTS AND DISCUSSION—*A. hydrophila* was recovered from all 25 lakes in the Central and North-Central Florida area. The *A. hydrophila* density ranged from 3 organisms/100 ml in Lake Kerr to as high as 12,000 organisms/100ml in Bivens Arm Lake. Although no attempt was made in this study to statistically correlate the trophic status of the lake with *A. hydrophila* densities (Rippey and Cabelli, 1980), higher *A. hydrophila* densities were observed as the trophic status of the lakes changed from

TABLE 1. *Aeromonas hydrophila* densities, temperature, pH and surface area of the 25 lakes sampled.

Lake	Surface Area (Hectares)	Temp C	pH	AH count (100 ml) Avg.	Range
Thonotosassa	819	16.9	6.95	2450	2000 - 2950
Bivens Arm	58	17.9	7.35	2530	1600 - 12,000
Alice	29	18.4	7.45	2500	1000 - 2800
Newnan's	2,433	16.0	6.40	2500	1100 - 3700
Wauberg	101	17.5	7.75	1800	1600 - 2000
East Tohopokaliga	11,968	18.3	7.15	1350	1100 - 1600
Francis	539	17.6	6.95	1320	1250 - 1530
Eustis	3,015	17.9	7.22	1350	1100 - 1600
Miona	418	19.3	7.05	1450	1300 - 1550
Blue Cypress	6,555	18.8	6.15	745	650 - 910
Sampson	2,042	16.0	5.80	800	700 - 900
Washington	4,362	19.5	6.48	980	800 - 1250
Santa Fe	1,674	15.0	6.30	650	200 - 1100
Placid	3,320	19.0	6.20	1050	1000 - 1350
Weir	2,301	18.5	6.25	1210	1118 - 1240
Ocean Pond	1,774	17.3	6.45	910	800 - 1140
Jackson	3,412	17.5	6.45	410	350 - 485
Kingsley	667	15.0	6.30	300	270 - 330
Panasoffkee	4,410	20.5	6.70	219	165 - 280
Winnott	85	17.8	6.95	143	90 - 196
Annie	86	18.9	6.85	150	80 - 320
Kerr	2,830	16.9	6.35	25	3 - 56
Geneva	692	15.0	6.20	36	32 - 41
Sheelar	28	18.5	6.00	63	40 - 86
Magnolia	83	15.0	6.40	39	27 - 50

oligotrophic to eutrophic. Hazen et al., (1978) reported that densities of *A. hydrophila* are high in the southeast United States. However, no Florida lakes were included in their study. Our study is believed to be the first in which the abundance of this organism in Florida lakes is reported.

The temperature of the lakes sampled ranged from 15.0-20.5 C (Table 1). Thus, it seems that temperature had no apparent effect on the recovery of *A. hydrophila*. The thermal optima for most strains of *A. hydrophila* is 35 C, and the thermal maximum is close to 45 C (Rouf and Rigney, 1971). However, in a recent work, researchers alluded to the importance of seasonal distribution of this organism for its recovery (S. S. Rippey, V. J. Cabelli, Abstr. Annu. Meet. Am. Soc. Microbiol. 1979, N1, p. 179). The authors stated that the ambient low water temperatures had an adverse effect on *A. hydrophila* densities. Measurements must be limited to water masses with temperatures of 15 C or greater. Table 2 shows that the lower range of temperatures during the Florida Winter apparently did not affect the recovery of this organism from Florida lakes.

The pH of the 25 lakes studied ranged from 5.80 to 7.75 (Table 2). Thus, as with temperature, pH had no apparent effect on the recovery of *A. hydrophila*. These results are in agreement with those reported by Hazen et al. (1978).

TABLE 2. Atypical genera isolated and identified from selected north-central Florida lakes.

Lake	Genus[a]
Geneva	*Enterobacter* spp (4)[b]; *Klebsiella oxycota* (2)
Sheeler	*Enterobacter* spp (10)
Magnolia	*Enterobacter* spp (4); *K. oxycota* (4)
Kerr	*K. oxycota* (4); *Proteus* spp (2); *Enterobacter* spp (5)
Annie	*K. pneumoniae* (3); *Enterobacter* spp (6)
Kingsley	*Enterobacter* spp (8); *K. oxycota* (2)
Panasoffkee	*Enterobacter* spp (6); *K. oxycota* (4)
Jackson	*Serratia* spp (4); *Enterobacter* spp (5)
Winnott	*K. pneumoniae* (4)
Blue Cypress	*K. pneumoniae* (2); *Citrobacter* spp (3); *Serratia* spp (4)
Sampson	*K. pneumoniae* (6); *Citrobacter* spp (2)
Washington	*Proteus* (2); *K. oxycota* (5); *Enterobacter* spp. (3)
Weir	*Enterobacter* spp (6)
Placid	*E. coli* (3); *Enterobacter* spp (5)
Santa Fe	*Enterobacter* spp (10)
Ocean Pond	*Citrobacter* spp (3); *Enterobacter* spp (6)
Miona	*Proteus* spp (3); *Enterobacter* spp (6)
Eustis	*Enterobacter* spp (6); *K. oxycota* (4)
Francis	*Enterobacter* spp (9)
East Tohopekaliga	*E. coli* (3); *Proteus* spp (2); *Enterobacter* spp (4)
Thonotosassa	*Serratia* spp (4); *K. pneumoniae* (2); *Enterobacter* spp (3)
Bivens Arm	*K. pneumoniae* (10)
Alice	*K. pneumoniae* (6); *Enterobacter* spp (4)
Newnans	*Enterobacter* spp (10)
Wauberg	*K. pneumoniae* (8); *Enterobacter* spp (2)

[a] Descriptions according to AH reactions (Kaper et al., 1979) and *Bergey's Manual of Determinative Bacteriology* (1974).
[b] Number of colonies isolated for each genus.

A distinct and typical combination of reactions is observed when *A. hydrophila* grows on AH medium (Kaper et al., 1979). Ninety-eight and six-tenths per cent of all the typical colonies examined were confirmed as typical *A. hydrophila* and 98.1% of all the atypical colonies confirmed as atypicals. These results show the selectivety of the mA medium for *A. hydrophila*. In addition, the AH medium offers an accurate and fast (18-24 hr) method for reconfirming *A. hydrophila* colonies isolated from natural waters. Table 2 shows the atypical genus isolated from the 25 lakes sampled. The genera were classified by their reaction on AH medium and their descriptions in *Bergey's Manual of Determinative Bacteriology* (1974). Most of the atypical bacteria isolated were *Enterobacter* spp. Other genus isolated were: *Klebsiella*, *Citrobacter*, *Proteus*, *Serratia* and *Escherichia*.

Thus, *A. hydrophila* seems to be widely-distributed in Florida lakes. The difference in abundance of this organism in lakes of different trophic status and their seasonal distribution in Florida lakes is currently under investigation. Winter temperatures did not affect the occurrence of *A. hydrophila* in the lakes studied. In addition, the mechanisms that allow *A. hydrophila* to proliferate in lakes of different trophic status are still unknown. Clearly, *A.*

hydrophila is an important component of the microflora of these aquatic systems and deserves additional study.

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NESTLING PELECYPODS—*David Nicol*, Box 14376, University Station, Gainesville, Florida 32604

Abstract: *Nestling pelecypods lack stout byssi. They live in crevices, rocks and holes left by boring pelecypods or dead barnacles. They characteristically have distorted shells that conform to the constricting cavity. Almost all nestlers have eulamellibranch ctenidia and all are marine suspension feeders. The earliest nestling pelecypods are probably Jurassic in age, but they increased greatly in diversity during the Cenozoic.*

Stanley (1970, p. 8) defined nestling as "living within a pre-existing cavity in a hard substratum, and lacking the ability to excavate such a cavity." On page 88, Stanley further commented, "Animals that nestle passively in cavities in hard substrata and lack the capacity for enlarging these cavities have distorted shells that conform to the shape of the constricting cavity." Solem (1954) used the distorted shape of species of *Trapezium* and *Coralliophaga* as evidence of a nestling habit. Thus, nestling pelecypods are those that occupy the holes left by boring pelecypods, dead barnacles, and other agencies which have caused cracks and crevices in rocks. Furthermore, true nestlers do not have stout byssi and seem to be able to seek and find these cryptic habitats.

This definition of nestling pelecypods would eliminate Kauffman's (1969) ecological groupings of byssate epifaunal nestlers and byssate fissure-dwellers. I do not consider the pelecypods that Kauffman places in these categories as true nestlers. This would also eliminate the so-called nest builders, those pelecypods that construct nests from their byssal fibers, and it would also eliminate those pelecypods that have a commensal relationship with sponges, tunicates, and various burrowing worms and crustaceans. A species of pelecypod may be found in an unusual habitat: I have seen specimens of *Atrina* lodged in the central cavity or atrium of a bath sponge. However, I do not consider *Atrina* a true nestling pelecypod. I have seen living specimens of *Sphenia*, which is a true nestler, collected from dead barnacles in Florida, although Abbott (1974) questioned their occurrence in Florida. A major problem is that few observations have been made on nestling species of pelecypods. Many nestling pelecypods are small in size and easily overlooked because they are found in cryptic habitats. Few nestling pelecypods attain a size of more than 60 mm.

My sources for the data shown in Table 1 come mainly from certain faunal monographs and are listed under the heading Literature Cited. I have followed the classification in the *Treatise on Invertebrate Paleontology*, although I believe that the Turtoniidae belong to the Veneracea, if not the Veneridae, and are not related to the Cyamiacea. In Table 1, I list the families, subfamilies, and genera of pelecypods that appear to be either well-documented as far as the nestling habit is concerned (e.g., some of the Hiatellidae, Trapeziidae, and Myidae) or those that likely have one or more species that nestle. Possibly other families should be added, such as the Ungulinidae, Sportellidae, Erycinidae, and Mytilidae, but few observations have been made on these families and the evidence of the nestling habit is in-

TABLE 1. Families, subfamilies, and genera of pelecypods, some of whose species are nestlers, with the first occurrence of the family or subfamily in the geologic record.

First Occurrence of Family or Subfamily		Genera
1. Malleidae	Jurassic	*Malleus*
2. Kelliidae	Paleocene	*Kellia*
3. Turtoniidae	Miocene	*Turtonia*
4. Semelidae	Eocene	*Cumingia*
5. Trapeziidae	Cretaceous	*Trapezium* *Coralliophaga*
6. Tapetinae	Cretaceous	*Irus* *Notirus* *Venerupis*
7. Petricolidae	Eocene	*Petricola* *Claudiconcha*
8. Myidae	Paleocene	*Sphenia*
9. Hiatellidae	Jurassic	*Hiatella*
10. Lyonsiidae	Eocene	*Lyonsia* *Entodesma*
11. Thraciidae	Jurassic	*Thracia*

conclusive. Some species of pelecypods consistently nestle, whereas others may or may not nestle. One species of a genus may be a nestler, whereas a closely related species may bore or burrow.

Nestling pelecypods are all marine suspension feeders. In this regard, *Cumingia*, which is a nestler allocated to the Semelidae, is most likely a suspension feeder, although most semelids are considered to be deposit feeders. Nestlers are rare in the Arctic, Antarctic, and the abyssal and hadal zones, being represented in these regions either by *Hiatella* or *Kellia*. In the lower latitudes, the diversity of nestling pelecypods increases greatly, and in areas of reef corals, nestling is most common.

The earliest occurrences of the families and subfamilies shown in Table 1 indicate that none of the nestling genera belongs to ancient stocks. Although the first occurrence of the Hiatellidae is given as Permian in the *Treatise on Invertebrate Paleontology*, the Permian genus *Roxoa* is doubtfully assigned to the Hiatellidae, and the family can confidently be traced back only as far as the Jurassic. Three of the families can be traced back to the Jurassic, 2 to the Cretaceous, 2 to the Paleocene, 3 to the Eocene, and one to the Miocene. With the exception of the Malleidae, the rest of the families and subfamilies belong to groups that have eulamellibranch ctenidia, which is a morphological feature that is not considered primitive. The first occurrences of these families that have nestling species appears significant. It seems that possibly no species of Paleozoic pelecypod was a nestler and that the first true nestling pelecypods did not appear before the Jurassic. Nestlers become more abundant in the Cretaceous, but diversity of nestlers increased greatly during the Paleogene. Nestlers are probably as common and diverse now as they have ever been. Even so, there are probably no more than 100 living species of nestling pelecypods in 11 families and 16 genera and subgenera.

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NOTES ON REPTILES FROM ISLA SAONA, REPÚBLICA DOMINICANA—*(1) Robert W. Henderson* and *(2) Richard A. Sajdak*, (1) Section of Vertebrate Zoology, Milwaukee Public Museum, Milwaukee, Wisconsin 53233, and (2) Milwaukee County Zoo, Milwaukee, Wisconsin 53226.

ABSTRACT: *The gecko* Hemidactylus brooki *and the boa* Epicrates f. fordi *are recorded from Isla Saona, República Dominicana, for the first time. Additional specimens of the iguanid lizard* Anolis baleatus lineatacervix, *which is endemic to Saona and was named on the basis of a single specimen, are described.*

ISLA SAONA is an islet of 111 km^2 situated 2 km off of the southeastern tip of the República Dominicana. Like most of the Hispaniolan satellite islands, Saona's herpetofauna is fairly well known (see Schwartz, 1977, for a list). However, recent field work (that was concentrated on the study of tree snakes [*Uromacer*]), has produced 2 additions to Saona's reptile fauna and additional examples of an *Anolis* lizard which was described on the basis of a single specimen. All specimens are in the herpetological collection of the Milwaukee Public Museum (MPM).

Anolis baleatus lineatacervix SCHWARTZ: Schwartz (1977) described *Anolis baleatus lineatacervix* on the basis of a single specimen. In June-July 1980 and February-March 1981 we collected 5 specimens, 4 of which (MPM 19024, 19042, 19500, 19505) were preserved; the fifth is still alive and will be deposited in MPM upon its death. A large (14.7 cm SVL) male (MPM 19024) was collected by day in heavily shaded mangrove (*Rhizophora)* swamp directly behind the village of Mano Juan on the south shore of Isla

Saona. It exploited perches between 1-2 m in height, and was dark brown when first observed and finally collected. All other specimens are females and were collected at night as they were sleeping at heights between 0.7-7.0 m. Two were seen at mangrove edge, and others were seen and/or collected in a narrow strip of scrubby trees and low bushes situated between coconuts and evergreen forest within 1.0 km east or west of Mano Juan. Although *A. b. lineatacervix* was not uncommon where we collected, we did not find that they were " 'about as abundant as *Uromacer [oxyrhynchus]* . . .,' " as did the collector of the holotype (Schwartz, 1977). We apparently collected in different habitat and saw 10-12 *Uromacer* for every *A. b. lineatacervix.*

Following are scale counts and a color and pattern description based on our 4 preserved specimens. All characters are as defined by Schwartz (1974); means are followed by ranges. Snout-vent length 14.7 cm in 1 male, 10.4-13.2 cm in 3 females; snout scales on level of second canthal 4.3 (3-6); vertical rows of loreals 6.3 (5-8); scales between supraocular semicircles 3.3 (3-4); scales between interparietal and supraocular semicircles 4-6/4-5; vertical dorsals 21.7 (20-23, based on 3 specimens); horizontal dorsals 17.5 (16-19); ventrals 25.3 (23-28); 1 row of scales between suboculars and supralabials; nuchal crest scales very high and body crest scales low; coloration, in life, of a 13.0 cm female is pale mint green dorsally with 4 whitish crossbands (plus one more on tail), supralabials and infralabials turquoise, top of head heavily mottled with chocolate brown, supraorbitals mottled green and brown, downward curved, brown postorbital stripe, poorly defined white supra-axillary stripe, brown streaks heavy on neck, fading posterior to level of axilla; dewlap sulfur yellow anteriorly, green and yellow medially and yellow to orange on posterior edge with 3 pale brown horizontal stripes on posterior half; a yellow streak with some small brown blotches runs from mental onto dewlap; venter very pale yellow-green with scattered scales of pale brown; tail greyish green with small white spots arranged irregularly, limbs and digits predominantly green with some brown markings. There is some variation in number and boldness of white dorsal crossbands, neck stripes and supra-axillary stripe, but all MPM specimens possess these characters. There is considerable metachrosis, ranging from mint green and turquoise blue to milk chocolate brown. The female maintained alive is green during the day and at night, if unmolested; if disturbed, it goes to brown.

Our specimens of *Anolis baleatus* strengthen Schwartz's (1977) argument for the subspecific distinctiveness of the Isla Saona population.

Hemidactylus brooki haitianus MEERWARTH: This gecko is widespread on Hispaniola, and its occurrence on Isla Saona is not unexpected. On 2 July 1980, two specimens (MPM 19026-27), a male and female, were collected at night as they perched near a light on the outside wall of a general store in Mano Juan. It is possible that the lizards were transported to Saona with supplies that went to the general store.

Epicrates fordi fordi GÜNTHER: *Epicrates fordi* is a small, slender, semiarboreal boid. The nearest main island locality from which it is known is about 170 km west of Saona. Schwartz (1979) recently reported a specimen from Isla Catalina, which lies 35 km west of Saona. We collected 2 specimens (MPM 18748 and 19025) of *E. f. fordi* on 27 June and 4 July 1980 respectively, and another (MPM 19506) on 1 March 1981. All 3 specimens were collected within 0.5 km W of Mano Juan; all are females. They were nocturnally active on low (1.5-2.0 m) vegetation in mangrove edge habitat. They were crawling slowly through the vegetation, presumably foraging for sleeping *Anolis*. The description that follows uses characters utilized by Sheplan and Schwartz (1974) in their review of Hispaniolan *Epicrates*; means are followed by ranges. Snout-vent lengths are 34.5-56.5 cm; ventrals 247.3 (245-250), subcaudals (for two specimens) 82 (81-83); ventrals + subcaudals (2 specimens) 328; supralabials 13-15/13-14; infralabials 15-16/15-16; circumorbital scales 10-11/9-11; pre-intersupraoculars 3, intersupraoculars 1, and post-supraoculars 3.3 (3-4); dorsal scale rows (neck-midbody-posterior) 33.7 (33-34)—36.7 (36-37)—21.0 (20-22); body blotches 65.0 (61-67), tail blotches 18.7 (16-20); dorsal ground color in all specimens is brownish grey, while blotches are dark brown and edged with black.

All 3 specimens agree in lepidosis and color and pattern with the description of Dominican *E. f. fordi* presented by Sheplan and Schwartz (1974).

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A GEORGIA STATION FOR *TORREYA TAXIFOLIA* ARN. SURVIVES

—*Thomas Savage*, Florida Department of Environmental Regulation, Tallahassee, Florida 32301

ABSTRACT: *A rich ravine woods, inhabited by many unique plants including* Torreya taxifolia *was cleared 27 yr ago. A recent survey has revealed that the system's major features remain, including a living* Torreya.

ONE of the Apalachicola River ravine systems which Hubbell, Laessle, and Dickinson (1956) described was a small, moist, rich ravine woods adjacent to the east abutment of the Jim Woodruff Dam. The rich mesic ravine, notable to the authors as the only station for *Torreya taxifolia* in Georgia, was not over 400m long and contained a very small, spring-fed, sand-bottomed brook, with steep slopes. Characteristic trees were ". . . loblolly pine *(Pinus taeda)*, sweetgum *(Liquidambar styraciflua)*, magnolia *(Magnolia grandiflora)*, southern red oak (*Quercus falcata*), tulip tree (*Liriodendron tulipifera*), basswood (*Tilia americana* var. *heterophylla*), hickory (*Carya tomentosa*), and sugar maple (*Acer barbatum*) . . ." The understory in the ravine bottom and lower slopes was composed of ". . . *Carpinus*, *Ostrya*, scattered *Torreya*, oak-leaf hydrangea (*Hydrangea quercifolia*), grape (*Vitis rotundifolia* and *Vitis* sp.), climbing hydrangea (*Decumaria barbara*), French mulberry (*Callicarpa americana*), woodbine (*Parthenocissus*), etc."

Such was the status in the spring of 1953. However, when re-visiting the following spring they found that the area ". . . had been completely devastated. All the large trees in the lower part had been cut and left as they fell, in a criss-crossed jumble; the entire ravine was open to the sun, and any thought of using it as a study area had to be abandoned." Consequently, it was abandoned as a site for longterm monitoring of the impact of the installation and operation of the dam. No further mention of this area has been made specifically; Wharton (1978) mentions the region as containing ravines characterized by *Torreya*, as do Godfrey and Ward (1978).

An informal survey conducted on 28 April 1981 revealed that the ravine is completely covered by a tree canopy and many of the trees forming the canopy are survivors of the original forest which suffered the destruction. There remains no evidence of the fallen timber referred to in the original description, leading me to believe they were removed subsequent to the previous workers' survey. Particularly impressive were several large southern magnolias, one very large yellow poplar and several large loblolly pine. Several hours were spent walking over the terrain, primarily in the upper and middle sections of the ravine, performing visual transects down one slope and up the other. In the process, one living *Torreya*, ca 1.5m tall was discovered at the upper end of the ravine on the south-facing slope, 15m above the stream. Several *Torreya* logs were observed in the same general area. Although a thorough botanical survey was not performed, the area had clearly recovered from the devastation described earlier, and with the protection associated with public ownership (U.S. Army Corps of Engineers) this site can be expected to continue to return to its former character.

Mr. Augus K. Gholson, Jr., resource manager of the Corps properties associated with Jim Woodruff Dam and Lake Seminole, guided me on a subsequent visit to the area on 10 May 1981. We surveyed several other ravines which lie within the boundaries of federal ownership, and also in Georgia (Fig. 1). One ravine lies immediately south of the "HLD" ravine (named in honor of the authors of the original botanical survey) just above the state line. This ravine and 2 of the 3 immediately to the northeast were surveyed. *Torreya* is represented by 2-3 dozen living specimens, two-thirds of which are located in the southern ravine. Occasional fallen specimens, long decayed, were also in evidence. These other ravines were not mentioned by Hubbell et al., (1956) and, while they would have been suitable as substitute stations for their study, it must be concluded that their survey was too far along to initiate a survey of new ravine. Certainly, *Torreya* was at least as well represented then as it is now.

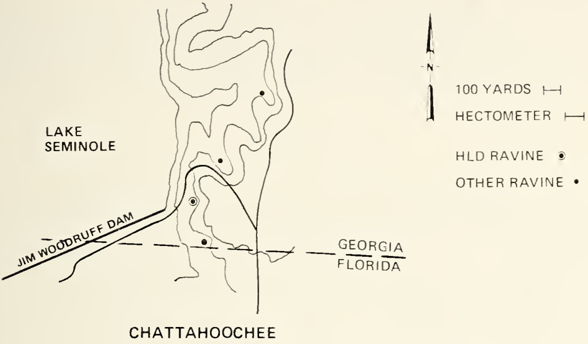

FIG. 1. Location of study areas in North Florida.

While stations for *Torreya* survive, it is not certain that the species will survive, because every tree seen during these 2 surveys showed evidence of invasion by a fungus, a condition first reported by Godfrey and Kurz (1962) and later more thoroughly described by Alfieri et al., (1967), who noted that seedlings as young as 6 mo exhibited symptoms of infestation. While the suspected agents of the disease (*Physalospora* and *Macrophma)* were not definitively proven to be the causes, application of maneb fungicide (1½ lb per 100 gal) resulted in improved conditions in the treated trees. (In a recent conversation, Dr. Alfieri reiterated the effectiveness of commercial fungicides on this disease, noting that use of the fungicide, Benomyl, would be expected to have topical and systemic effects. He also reiterated his hypothesis that the fundamental cause of decline of *Torreya* was its inability to withstand exposure to full sunlight, thereby suggesting that clearing of the forests stressed the trees, leading to susceptibility to invasion by fungi.)

In conclusion, Georgia and Florida are the sites of the remaining specimens of the endangered *Torreya*, apparently threatened with extinction by agents whose eradication or amelioration is within the power of public agencies charged with their care. I hope that the appropriate state agencies will be encouraged to save the species.

ACKNOWLEDGMENTS—Discussions, particularly in the field, with Dr. Robert K. Godfrey and Mr. Angus K. Gholson, Jr. contributed greatly to my understanding of *Torreya*. Coincidentally, Dr. Richard Stalter visited the ravines several times shortly before my own visits, but unknown to me. A recent conversation and subsequently written report corroborate my own findings. Dr. Stalter was greatly supportive of the effort to save *Torreya*.

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ESTABLISHMENT OF *MELALEUCA QUINQUENERVIA* SEEDLINGS IN THE PINE-CYPRESS ECOTONE OF SOUTHWEST FLORIDA

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Abstract: *Site-season combinations were sought which might reduce the invasion potential of the exotic tree, melaleuca* (Melaleuca quinquenervia), *by subjecting germinants to lethal stresses. Seeds were sown 12 times during a 15-mo period on 2 study sites in an undrained area of Lee County, Florida. The sites represented the wet and dry ends of an ecotone between cypress* (Taxodium *spp.) and slash pine* (Pinus elliottii var densa) *communities. No season was totally lethal at either site, based on seedling presence 5 mo after sowing. Establishment was never dense, but was rarely zero. Some seeds germinated 6 mo after the majority of seeds in the same sowing. Freely available moisture was essential for germination and establishment—prolonged surface flooding was inhibitory. All seedlings grew slowly. A management strategy is suggested to minimize the invasion potential from isolated melaleuca seedtrees.*

Melaleuca *(Melaleuca quinquenervia* (Cav.) Blake) is a rapid-growing tree from Australia that has spread across significant portions of south Florida. Attempts to control the tree with fire, herbicides, felling, and bulldozing have been thwarted by the dense regeneration that often results. In this species, the seeds are stored on the tree in closed capsules until natural or man-made injury interrupts the transpiration stream and triggers seed release. Control attempts will continue to fail until an efficient method is found to consume the seeds, either on the tree or after they fall to the ground.

I tested the hypothesis that when seeds are released onto a site at the end of the wet season, viz., October, germination will immediately ensue and mortality during the following dry season will present establishment. Myers (1975) tested this hypothesis in southwest Florida. Eleven monthly sowings of melaleuca seeds were made in 8 habitats: *Pinus palustris* upland, *Laguncularia-Spartina* salt marsh, *Cladium* marsh, *Taxodium* scrub, and 4 types of *Taxodium* swamp. Myers' results were inconclusive in that establishment did not occur on many site types that are known to be vulnerable to melaleuca invasion.

The present study focused on direct seeding within one basic site type: the ecotone between cypress wetlands and pine flatwoods. Myers (1975) suggests that this ecotone is well suited for melaleuca invasion, and Duever et al. (1979) indicate (based on duration of surface flooding) that a relatively empty niche exists in that zone—too wet for pineland species, too dry for wetland ones.

METHODS—Two study sites were 0.9 km apart in Lee County, Florida (Sec. 20, T46, R26), 18 km southeast of the Page Field Airport. The general area fits Davis' (1943) detailed description of "pine flatwoods". One study site lay at the transition zone between an open pine stand and a slightly wetter grassland. The principal change in species composition across the zone was the elimination of pine (*Pinus elliottii* var. *densa*), because wiregrass (*Aristida stricta*) dominated throughout. The second site lay at the transition zone between a cypress swamp and its slightly more elevated grassy perimeter. *Taxodium distichum* and *Myrica cerifera* formed the swamp overstory, and forbs its understory. The grassy perimeter supported a diverse community of grasses, including wiregrass, and most forbs of the swamp. Study plots were placed on the tree side of the woodland/grassland border at each site. Sites were labelled "pine" and "cypress" although only the fringe of each community was represented. Neither site was under the direct influence of artificial drainage.

The experimental layout consisted of 6 blocks per site; each block contained 12 1-m^2 plots. Three blocks were placed inside a discrete clump of melaleuca reproduction and 3 just outside it. Clumps consisted of a dense growth of vigorous, seedless saplings less than 4 m tall. Seedtrees (responsible for the clumps) were removed before the experiment began. Within blocks, plots were located subjectively to minimize intrablock differences. One plot in each of 3 cypress blocks was sown on 31 Aug 1977 to test the feasibility of the treatment procedure. Formal sowings began in December 1977 when one randomly-selected plot in each block was sown. The next 3 sowings came at 2-mo intervals; the remaining 8 at 1-mo intervals.

Four water table observation wells were installed at each site. Wells were small plastic pipes, 150 cm long.

A composite sample of the upper 15 cm of mineral soil was collected from each block and analyzed for pH and double-acid extractable nutrients. No differences were found between sites or between blocks originally invaded or uninvaded by melaleuca. Mean pH of all groupings was 7, with individual values ranging 6.1-8.2 (both extremes at pine site). Available K, P, and Mg were extremely low: 4, 0.4-0.7, and 4-8 ppm, respectively.

All melaleucas were cut at the beginning of the study, and sprouts were removed monthly. Native vegetation was cleared when a plot was seeded. Plot preparation partially simulated a fire: all plants were cut 1 cm above the ground, the litter layer was swept away, and regrowth was permitted. Thus, established melaleucas were eliminated from entire blocks, whereas native plants on individual plots were only temporarily disturbed. Native vegetation was sparse on plots formerly occupied by melaleuca, however.

On each plot, 25 seeding spots (5 x 5 @ 20 cm spacing) were marked with plastic cocktail picks. Approximately 600 (≅ 120 germinable) seeds were extracted from a water-filled vial and deposited at each seed spot using a bulb syringe with a 2 mm orifice. Melaleuca seeds will not float if they have been thoroughly wetted, so seeds for flooded plots were soaked just prior to sowing in an aqueous solution containing 0.002% WEX® (an agricultural wetting agent). Soaks for seeds deposited on unflooded plots contained no wetting agent because the concentrating of the wetting agent by evaporation might have harmed the seeds. The wetting agent and solution concentration were chosen after a laboratory test showed that the accepted combination affected neither speed nor completeness of germination. Several seed lots (composites from 2-4 trees) were used in the sowings. Bimonthly germination tests assured the vigor of these seedlots.

At monthly intervals, "plot occupancy" (the number of sowing spots, out of a possible 25, occupied by at least one seedling of any size or state of health) and heights of seedlings taller than 2.5 cm were recorded on all previously sown plots. A magnifying glass helped distinguish melaleuca germinants from those of other species. Water levels were also measured monthly.

Independent analyses of variance were run for data taken 1 and 5 mo after sowing, and for the maximum value observed at any visit. Prior to analysis, the arcsine-square root transformation was applied to the percentage of seed spots on each plot containing at least one live seedling. Because variance structures were not comparable between cypress and pine sites, hypotheses concerning differences due to prior invasion status, sowing dates, or their interactions were tested on separate data sets for the pine and cypress sites. Only overall site differences were tested with complete data sets.

RESULTS—Differences between the pine and cypress sites were significant (α = .01) using either 1-mo, 5-mo, or maximum observations. The pine site had fewer plots containing established seedlings and fewer seedlings within those plots than the cypress site. At both sites, plots in areas that were occupied by melaleuca prior to the study were no more (or less) favorable for establishment than those in the uninvaded areas (α = .10), and invasion status did not interact significantly (α = .10) with the date of sowing. However, differences in plot occupancy among sowing dates were highly significant (α = .01).

Those sowing dates that resulted in the highest plot occupancy after 1 mo did not, with the exception of September, have the highest after 5 mo (Table 1). The February sowing (Fig. 1) illustrated that when favorable germination conditions were soon followed by a prolonged dry period, the germinants died, leaving little germination potential available after the rains resumed. Conversely, seed applied during a dry period had low or no initial

TABLE 1. Seedling occupancy of plots in relation to time of sowing and length of exposure.

	Percent Occupancy[1]					
	Cypress			Pine		
Sowing Date	1 mo.	Max.	5 mo.	1 mo.	Max.	5 mo.
Dec. 77	86.3	96.5	36.7	13.8	43.1	0
Feb. 78	93.9	93.9	3.0	82.4	82.4	0.1
Apr. 78	*0.9*	*71.8*	*9.1*	*0*	*21.2*	*4.6*
Jun. 78	30.7	43.8	19.0	22.7	28.6	10.2
Jul. 78	*1.8*	*33.2*	*22.2*	6.9	17.5	5.8
Aug. 78	*0*	*72.9*	*55.9*	21.3	42.5	16.4
Sept. 78	98.7	99.3	87.8	77.7	80.1	8.0
Oct. 78	*65.0*	*84.8*	*74.8*	25.1	35.5	0.7
Nov. 78	*35.3*	*84.2*	*40.5*	*0*	*60.8*	*6.2*
Dec. 78	78.5	93.8	13.2	80.2	80.2	1.3
Jan. 79	99.0	99.9	16.6	68.0	68.0	5.7
Feb. 79	88.0	88.0	32.2	*1.0*	*44.8*	*6.1*

[1] Occupancy is the mean percentage of 6 plots, back-transformed from arcsine-square root units. Sowings resulting in a greater occupancy at 5 mo than at 1 mo are italicized. Maximum occupancy occurred within 5 mo, except for July (see Fig. 1).

germination, but when rains resumed, much of the germination potential was still available. Duncan's multiple-range test on differences between sowing dates after 5 mo confirmed that for the cypress site September and October sowings had more "establishment" than all other sowings except for August ($\alpha = .05$). February 78 counts were lower than those for Feb 79 ($\alpha = .05$), indicating the importance of year-to-year differences. Differences among sowings at the pine site were minor, because all values were generally low. There, the only real differences ($\alpha = .05$) occurred between the June or August sowings (high) and the December or Feb 78 sowings (low).

Surface flooding never occurred on the pine plots, but 1-4 cm of water covered the cypress site during much of July and August (Fig. 2). Uniform flooding following the August sowing prevented germination until the water table dropped in late September. The July sowing had some initial germination, most of which died during the flooded period (Fig. 1).

Because seeds were placed at discrete points within the plot, the effects of different microsites were observable. Litterfall from overstory trees enhanced survival of germinants. Forb growth and algal mats reduced survival at the cypress site but algal mats did not form where litter had not been artificially removed. Crayfish buried some seed spots; these spots were treated as missing data in the analysis.

Seedling height growth was slow. Seedlings from the pilot sowings at the cypress site in August 1977 were less than 10 cm tall a year after sowing. Height growth was greatest in late spring and early summer when rains began to raise the water table (i.e., moist but aerobic soil), and in the autumn when the water table began dropping. Growth between June and August 1978 was slow and reflected the flooding of the soil surface, even though these seedlings were not submerged. Growth was negligible between January and April 1979 and probably resulted from a combination of low temperatures and low water tables. Twenty months after sowing, with the onset of summer rains, the 20-cm tall seedlings assumed the rapid growth typical of seedlings and saplings of this species.

Few seedlings from the formal sowings (none after the September one) were taller than 5 cm in May 1979. At the cypress site, the April sowing had 5, and September 1, seedling taller than 10 cm. No seedling survived there from the February 1978 sowing, but at the pine site, 2 seedlings remained from the same sowing and both were taller than 20 cm (no other sowings on either site had seedlings taller than 20 cm). Seeds sown at the 1800 spots at the pine site resulted in 4 seedlings taller than 10 cm and 15 taller than 2.5 cm.

DISCUSSION — Better development at the cypress site resulted from greater initial germination, better moisture relations after germination, and a soil surface with visibly enough organic matter to give it cohesive resistance to rain splash. The sandy soil surface of pine plots became bleached within 4 mo of clearing, indicating a loss of organic material. The impact of large

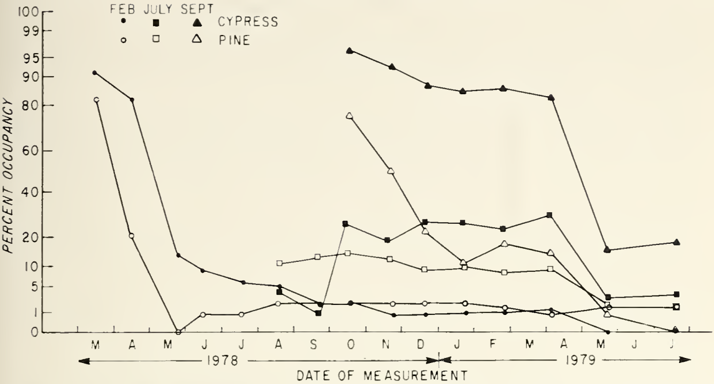

FIG. 1. Proportion of seeded spots containing a live seedling on pine and cypress plots sown in February, July, and September. Each point is the mean of 6 plots (= 150 seed spots). The ordinate axis is distorted due to the arcsine-square root transformation.

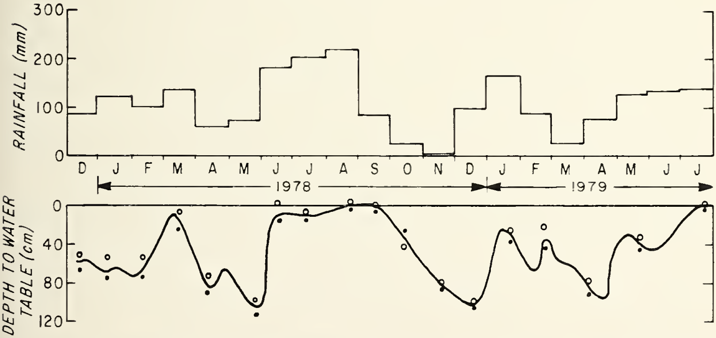

FIG. 2. Rainfall and water table levels during the study. Rainfall is the weighted average of observations at 3 permanent installations located 9-18 km away. Depth to water table is the mean depth observed in 4 wells each at cypress (o) and pine (•) sites. The smooth curve is based on a continuous record of water level at a nearby study site.

raindrops churned this unstructured surface, loosening the 5-mm tall germinants' fragile attachment to the soil and increasing their vulnerability to water stress. During late spring, intense solar radiation and low water table created a dry plus hot surface.

Obvious differences were detected among seasons in melaleuca germination, establishment, and height growth. Generally, wet months were more favorable than the remaining drier months, but because surface flooding was inhibiting, only the beginning and end of the wet season were favorable on the cypress site.

Periods of little or no establishment are of most relevance to melaleuca control programs. Figure 1 shows that the late spring dry period of 1979 killed most seedlings, including the generally vigorous ones from the September sowing. Nevertheless, numerous seedlings existed after that dry period. Two processes were responsible: (1) A narrow set of genotype/microsite combinations permitted survival of a few established seedlings and (2) Some seeds failed to germinate with their cohorts so were not lost during the dry period. Thus some plots contained no seedlings 5 mo after sowing, but contained substantial numbers at the last observation because of delayed germination. Seeds were relatively long-lived on/in the soil. I found (Woodall, unpublished) seeds lost no germinability after 10 mo of shallow burial in a swamp soil that fluctuated between saturated and unsaturated conditions. Seeds buried in a well-drained saw-palmetto prairie soil lost two-thirds of their germinability by 10 mo. Burial in both cases prevented germination. Whether rain splash on sandy soils can bury seeds deep enough to inhibit germination is unknown. "Rain plowing" possibly explains delayed germination in that it continually brings some seeds to the surface while burying others. A more likely explanation, however, is the variable germination response of seeds under field conditions.

Water stress at the study site would have been greater if winter precipitation had been closer to the long-term average. The winters of 1978 and 1979 were unusually wet (Fig. 2), so water tables did not drop as low in April and May as is typical. Wide variations from long-term precipitation averages are not unusual in south Florida. Drier spring weather would have killed more seedlings, but would have had little effect on ungerminated seeds.

Seedlings from seeds whose germination was delayed by flooding were stunted, but the probable cause was conditions during and immediately after germination rather than exposure to flooding. For example, seeds sown in August germinated as soon as conditions became marginally acceptable. Conditions marginal for germination were even less favorable for growth and germinants became stunted. Fresh seeds applied just 2 wk later showed favorable germination and growth.

Considering the number of seeds sown per spot, establishment was never truly abundant, but most plots usually contained a few seedlings. To use an electrical analogy, establishment was not a function of an environmental on/off switch, but of variable resistances. The summed resistances of moisture deficiency or surplus, high surface temperatures, rain splash, algal mats, plant competition, etc., rarely, under the conditions of this study, reached a high enough level to completely eliminate seedling establishment.

The lack of differences in establishment between previously invaded and uninvaded areas suggests that borders of the original melaleuca clumps resulted from transient phenomena, such as seedfall or fire patterns, rather than from fixed edaphic or topographic features.

Initial height growth under field conditions is understandably less than the 20 cm in 2 mo observed in a greenhouse, but is not always as low as that in this study. Melaleuca establishment often follows fire. Plot clearing in this study only partially mimicked fire's seedbed preparation as nutrient enrichment did not occur. Seedling success on a fire-prepared site would probably be greater.

I show that seedling establishment is possible even when environmental conditions are poor. Thus, the probability of invasion will generally be greater than zero, except on those obviously inappropriate sites, such as tidal mangrove or sandhills. The following recommendations are suggested.

MANAGEMENT RECOMMENDATIONS—Where seed-bearing melaleuca trees are scattered widely throughout a pine-cypress mosaic, the following steps should minimize the likelihood of a serious invasion.

(1) Kill trees and release seeds anytime from late October to late December. Herbicide injection into standing trees will be most effective. If fire has occurred since the summer wet season, delay this step one year. Showers from cold fronts during the winter should provide sufficient moisture to trigger germination. Absence of fire will promote plant competition and reduce available nutrients, thereby slowing the growth of melaleuca germinants. The normal spring drought should kill most of those germinants. Onset of the summer wet season should germinate most remaining seeds.

(2) The following dry season (November to April), run a moderately hot fire across areas suspected to contain seedlings. The fire may kill some seedlings but its primary purpose is to trigger a third period of possible germination. Those seedlings that survive the fire plus any new germinants may be stimulated by the fire, but should be few in number.

(3) Two years after the first treatment, remaining seedlings should be large enough to spot and should be grubbed out or treated with herbicide. Herbicides are best applied in September, when growth is vigorous.

Step 2 should be withheld from areas wetter than the cypress study site. Rather than try to bring seed out of soil storage with fire, one should minimize surface disturbance for several years while the establishment potential of those stored seeds eventually diminishes to zero.

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Earth Sciences

THE FLORIDA FREEZE OF 13 JANUARY 1981: AN IMPACT STUDY OF WEST-CENTRAL FLORIDA

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Abstract: *During the past 3 yr, meteorological anomalies have occurred with considerable regularity along the west coast of Florida. On 13 January 1981, a well-developed area of high pressure over southern Mississippi resulted in one of the most severe freezes recorded in the 20th century. Temperatures ranging from -7°C in the southern part of the region to -13°C in the northern section were officially recorded. Substantial agricultural damages were sustained, with the greatest financial losses occurring in the citrus industry. In addition, the freeze damaged many areas of natural vegetation, especially mangrove.*

During the past 3 yr, meteorological anomalies have occurred with considerable regularity along the west coast of Florida. They have ranged from floods and droughts to severe freezes and even snow (1979). In addition to the 1981 freeze discussed in the paper, the region also experienced a record-tying drought. Also, during the subsequent spring, the Tampa International Airport reported the worst drought on record for July 1981, normally the wettest month of the year.

The severe Florida freeze of 13 January 1981, blanketed most of the state, but particularly affected West-Central Florida, as the lowest temperature (-13°C) and the longest hourly duration below -2°C, 14 hr, were recorded there. Because of the varied agricultural economy in West-Central Florida, the damage was widespread, although the crops were not equally damaged.

It is because of these meteorological occurrences and the severity of the agricultural damage that this region was selected for discussion in this paper which will focus primarily upon 2 topics: (1) meteorological and topographical causes for the severe temperature drop and (2) the damaging effects to agriculture and natural vegetation.

METEOROLOGICAL AND TOPOGRAPHICAL CONDITIONS—Since 1937, the state of Florida has experienced 16 severe winter freezes. The lowest temperatures were recorded in January 1940, December 1957, and January 1981. During the early morning hours of 13 January 1981, however, along the west coast region of the state, record low temperatures for this period were officially logged. Temperatures ranging from -13°C to -4°C were common in Citrus, Sumter, Pasco, Hernando, Pinellas, Hillsborough, and Manatee counties (Fig. 1). The duration of temperatures below -2°C in these counties ranged from 7 hr in Manatee County (south) to 14 hr in Hernando County (north). The temperature distribution is clearly shown here on the 2

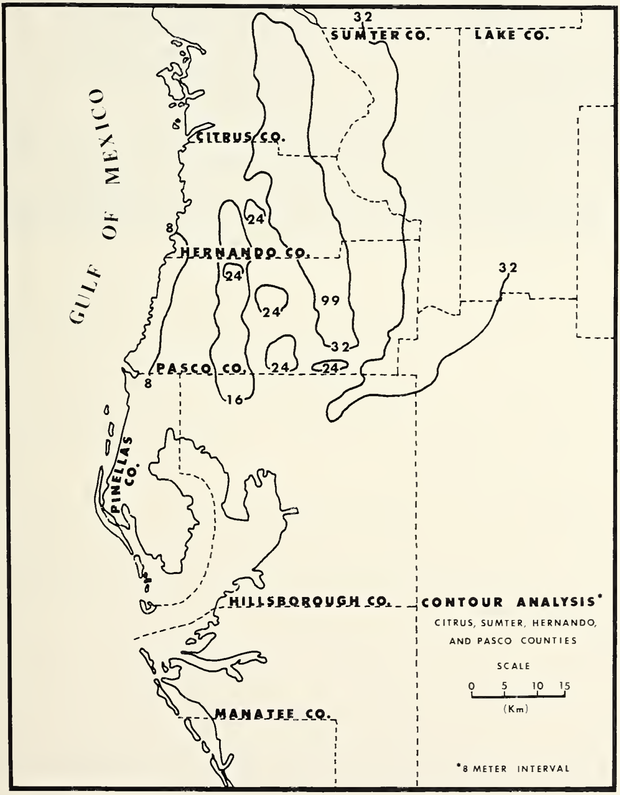

FIG. 1. Distribution of minimum temperatures in West-Central Florida, 13 January 1981.

charts provided by the U.S. Weather Service's severe freeze forecast computer (Fig. 2). The information shown on these 2 charts was obtained from temperature sensing via satellite at 2200 EST on 12 January and 0800 EST on 13 January.

The meteorological conditions which initiated the severe freeze can be traced on the 0700 EST surface map of 12 January 1981 (Fig. 3). A well-developed area of very high pressure (1040 mb) centered over the south-central Mississippi Valley, dominated the weather over the eastern third of the country. During the next 24 hr, the center of high pressure moved rapidly in a southeasterly direction to a position approximately 150 km south of Pensacola, Florida, while the surface pressure dropped to 1028 mb. This resulted in a northerly flow of winds throughout most of the Florida peninsula. During the pre-dawn hours of 13 January, the light winds (5 kt or less) resulted in a deep surface inversion along the west which is shown graphically by the acoustical sounding record taken at the University of South Florida on that date (Fig. 4). The inversion averaged 100 m in depth and persisted until about 1000 EST.

An examination of the 500 mb chart for this date indicates: (1) the extension ridge of high pressure aloft, with a pressure gradient ranging from 546 mb over northern Georgia to 564 mb over extreme southern Florida. (2) a northwest to southeast orientation of the isobars which enhanced the northly flow (65 kt) at the surface. These 2 factors increased the probability of unusually low surface temperatures (Fig. 5).

Plotted official minimum temperatures during the early morning hours of 13 January revealed an interesting distribution pattern (see Fig. 1). While one might normally expect temperatures to moderate from the northern to the southern part of the region, particular areas of colder temperatures are easily observed. These cold pockets were the result of wind flow patterns in relation to 2 ridges (Fig. 6) which parallel the coast from northern Citrus County to northern Hillsborough County, a distance of approximately 83 km. (U.S. Air Force Navigational Chart—February 1961). Each ridge has an average width of 13 km.

The highest point of elevation along this ridge, 99 m, occurs approximately 10 km due south of Dade City, located in east central Pasco County (see Fig. 1). Much of the land east and west of the ridge has an elevation of less than 15 m and is poorly drained. Therefore, the air drainage from the ridge in conjunction with the light winds resulted in the lowest temperatures recorded.

There are 2 apparent anomalies on the maps. These are Brooksville, located in central Pasco County and Center Hill in west central Sumter County. Both of these towns are situated on the ridge but have very low temperatures taken at reporting stations that are both located at considerably lower elevations. (All statistical data: U.S. Weather Service Records).

The importance of this severe freeze is reflected by the damages sustained

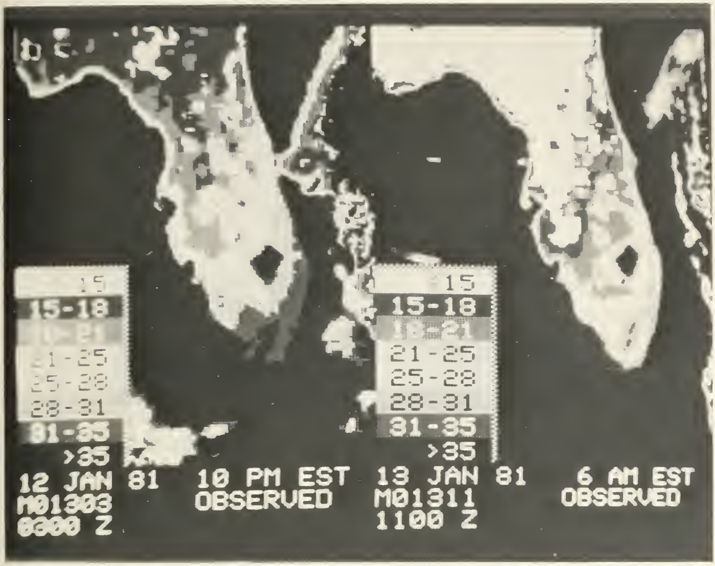

Fig. 2. Computerized depiction of temperature trends obtained from satellite sensing. (Courtesy of USWS, Ruskin, Florida).

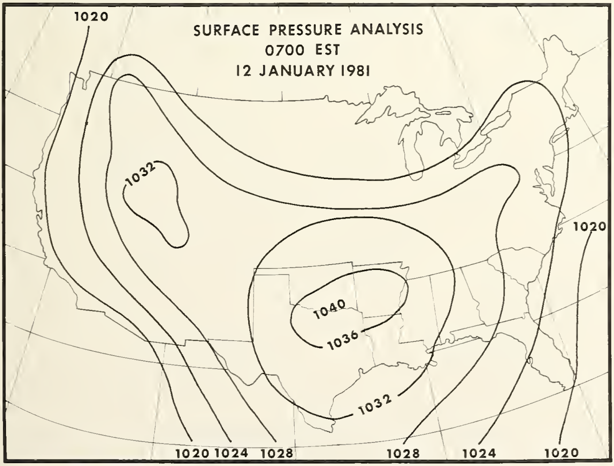

Fig. 3. Analysis of surface isobars indicating the development of a very strong high pressure system over the southern Mississippi valley at 0700 EST, 12 January 1981.

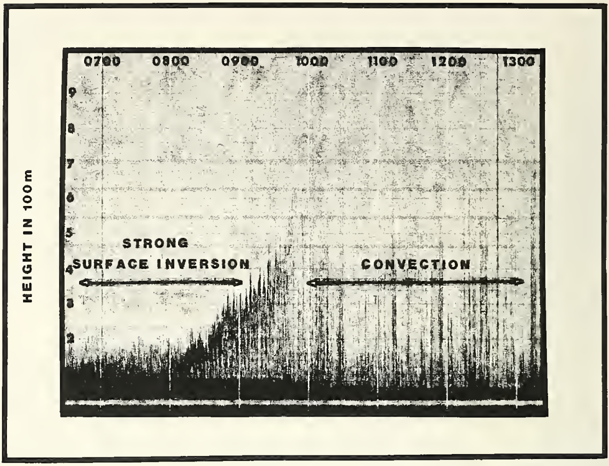

FIG. 4. Acoustical sounding taken at USF weather station showing a strong, pre-dawn surface inversion on 13 January 1981.

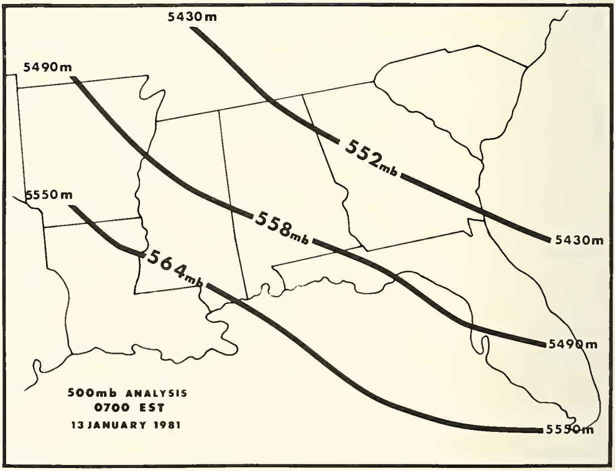

FIG. 5. Analysis of the 500mb chart indicating strong northerly flow aloft.

by the agricultural and related interests of the region. The following damage assessment is the best available at this writing.

Regional Freeze Damages—Following the 13 January freeze, 48 of Florida's 67 counties reported freeze damage. Within these counties there are 39,359 farms of which 68% or 26,734 were affected by the freeze (interview, Ron Keller). The total damage to agricultural products for the state has been assessed by the United States Department of Agriculture to be $572,083,444 with the greatest dollar loss in the citrus industry. In the 7-county area of West-Central Florida there are 6,034 farms with 74% or 4,446 of these reporting freeze damage. The total dollar loss for the area was $36,936,566 (interview, Zant). Most of the freeze related damage was a

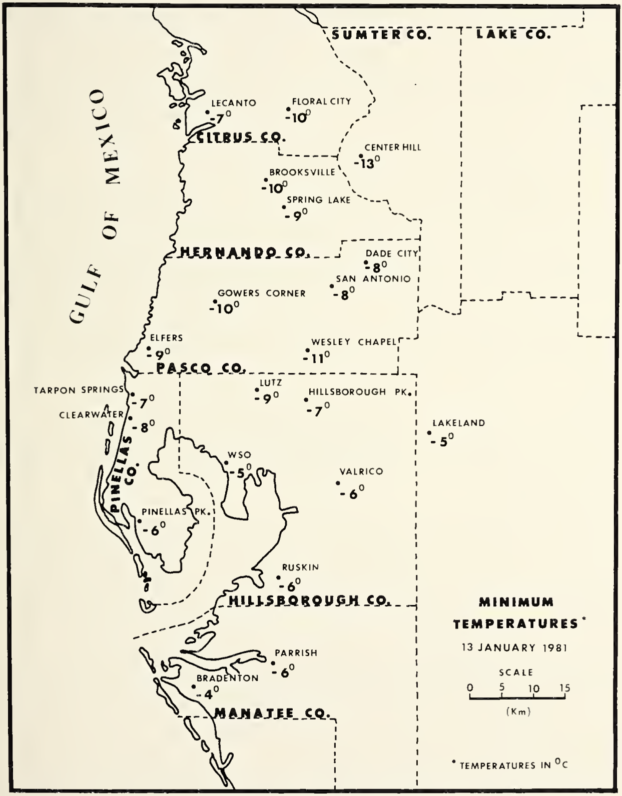

Fig. 6. Air drainage along 2 ridges parallel to the coast enhanced the development of the lowest temperatures within the region.

result of the duration of temperatures -2°C or below for 4 or more hours (F.C.L.R.S., 14 January 1981).

Citrus: All 7 counties of the West-Central Florida region reported damage to citrus with an estimated fruit loss of $23,470,566. This figure represents 69% of all dollar losses within the region in the 4 categories shown in Table 1 (U.S.D.A., 1981).

Prior to the freeze, the West-Central Florida orange production was predicted at 27,202,000 boxes and the total grapefruit production at 3,180,000 boxes (F.C.L.R.S., 10 December 1980). On 1 February 1981, an initial grove survey in the West Coast region indicated that an average of 68% of all early and midseason oranges and 65% of grapefruit were affected by the freeze with damage to the fruit centers being 24% and 35%, respectively (F.C.L.R.S., 11 February 1981). As of 1 April 1981, a survey indicated damage to 93% of the late Valencia oranges with dehydration damage to the fruit centers being 72% (F.C.L.R.S., 9 April 1981). The final estimate of total loss of fruit is in Table 1. The figures in Table 1 indicate the percentages of fruit which were so injured as to be rendered unusable. Although the fruit losses in the West-Central region ranged from 20% to 45%, the average loss was computed to be 29%.

The damage to citrus resulted from rot, droppage, and dehydration. Because approximately 95% of all Florida oranges are processed, especially as frozen concentrate orange juice (FCOJ), dehydration is an important factor resulting in lowered juice yields. The 9 January 1981 forecast was for a yield of 5.19 l per box; however, the final yield has been established to be 4.58 l per box (F.C.L.R.S., 9 January 1981). The loss of fruit and the lowered yields have resulted in an estimated loss of 52,995,765 of l (38%) FCOJ from West-Central Florida. The statewide reduction in FCOJ has been 36%.

The citrus production, finalized 28 September 1981, indicates that the West-Central Florida region experienced a 19% loss. Although this is lower than the estimated 29%, it still represents a significant loss (F.C.L.R.S., 28 September 1981).

Not only did the freeze cause a loss in the current fruit crop but the trees sustained damage that will affect future crops. The Florida Cooperative Extension Service reports that past experience with cold-damaged citrus trees has indicated that long-term production decline may be expected from trees with 30% or more cold injury (Bulger and Carte, 1981). Further, some trees may never attain yields that were customary prior to injury. The cold weather that preceded the freeze placed the citrus in a more dormant condition; this lessened the subsequent freeze damage. However, in West-Central Florida, some 29% of all citrus trees received cold-related injuries that will severely retard their potential production. Damaged trees which recover will require 3-5 yr to replace their former canopy bearing surfaces. As a result, this region, as well as the entire state, can expect lower yields for the next 5 yr. This may further the current trend, especially in Pinellas and

TABLE 1. Damage Assessments, Citrus, Sumter, Hernando, Pasco, Hillsborough, Pinellas, and Manatee counties, January 13-14, 1981 freeze.

County	Citrus Loss		Strawberries Loss		Vegetables Loss		Ornamentals Loss	
	%	$	%	$	%	$	%	$
Citrus	20	$ 613,200	100	2,000	-	-	-	-
Sumter	20	756,000	-	-	10	25,000	100	24,000
Hernando	25	1,400,000	-	-	-	-	-	-
Pasco	30	8,100,000	-	-	-	-	-	-
Hillsborough	30	11,526,366	20	7,200,000	-	-	?	2,000,000
Pinellas	45	1,000,000	-	-	-	-	-	-
Manatee	30	75,000	100	275,000	10	150,000	50	2,000,000
Total		23,470,566		7,477,000		175,000		4,024,000
% of Area $ Crop Loss	64		21		1		10	
% of State $ Crop Loss	10		100		.2		10	

Hillsborough counties, of converting older and damaged groves into residential suburbs.

Vegetables and Strawberries: The tomato crop sustained the greatest dollar loss of all vegetables. Although the state loss is estimated to be $105,094,600 the West-Central Florida region received virtually no damage. In anticipation of a possible January freeze, the growers in this area do not plant until the first week of February. One farmer, who wished to "jump the market," planted 30 acres of which 33% were frozen (interview, F. Butler). Manatee County reported a 10% loss to other vegetables amounting to $150,000.

The strawberries suffered more severe damage than did other truck crops. Plant City in Hillsborough County promotes itself as the "Winter Strawberry Capital of the World" and damage here amounted to $7,200,000. Damage was kept to a 20% loss as fields were flooded and allowed to freeze which protected the plant roots. Manatee and Citrus counties lost 100% of their crops valued at $275,000 and $2,000, respectively. These 3 counties represent 100% of the state's $7,477,000 revenue loss in strawberries.

Poultry: Masaryktown, located primarily in Hernando County, is an area of chicken farms which represent one of the largest egg-producing areas in the southeastern United States. Following the freeze, 7% of all chickens were lost, with the majority being older birds (interview, R. U. Beiter). No estimate of loss in revenue has yet been ascertained.

Improved Pasture: There has been a significant growth in the livestock industry in West-Central Florida during the past 15 yr. Only Hillsborough and Pinellas counties reported damage to improved pasture within the region, with an estimated 20% loss in each county, for a total of $1,790,000 (U.S.D.A., 1981). These data include damage sustained not only from the freeze, but also from the concurrent drought.

Ornamentals: Hillsborough, Manatee, and Sumter counties reported heavy damage to ornamental nursery stock, with revenue losses in excess of $4,000,000. The smaller shrubs and potted plants were injured more severely, whereas larger trees sustained less cold damage, except, perhaps, Norfolk Island pines.

Tropical Fish: The tropical fish industry occupies approximately 200 hectares southeast of Ruskin in southern Hillsborough County. These farms raise fish to be sold wholesale throughout the United States. Although some ponds were covered with protective plastic, the damage was severe. Most farms suffered a minimum loss of 75% and several with a total loss. Some species, such as the Sphenaps Mollies, were destroyed completely. Most of the loss incurred was to the mature fish that were ready for market. Therefore, the breeders had to maintain younger fish for 3-4 mo before they could be sold. Estimates of dollar loss were not available, although the overall income was down by some 80% (interview, Richard Graves).

Mangrove: In addition to the damage to commercial endeavors, the

January freeze injured many areas of natural vegetation. Especially vulnerable were the few remaining areas of mangrove. Already threatened by development along the waterways, the mangrove suffered light to severe damage throughout the region. The most severely damaged area was the northwest Tampa Bay shore of Pinellas County and recovery here has been slow. Although the mangrove areas are protected by county ordinances, the Pinellas County Environmental Office has issued numerous permits since January 1981, to cut the severely damaged areas in order to encourage a new growth (interview, McDonough). Because this cutting was extensive, another freeze in the near future may completely destroy the mangrove of this area.

Conclusions — Although the freeze of 13 January 1981 was a major one, the resultant damage was less than first anticipated. Two factors which contributed to this decrease in damage were: (1) new methods of freeze protection, and (2) modern methods of forecasting. This freeze allowed the first assessment of a low-volume under-the-tree irrigation system as a method for citrus grove heating. The citrus groves in which this system was utilized appear to have sustained substantially less damage than groves using other methods of protection. In addition, the installation in 1980 of the US Weather Service's satellite sensing computer system enabled a more precise evaluation of hourly trends in temperature change (interview, F. Crosby).

Despite the applications of modern forecasting techniques and new methods of crop protection, if the west coast of Florida continues to experience significant variations in its established weather patterns, a reevaluation of present agricultural endeavors will be required.

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Biological Sciences

INFLUENCE OF VARYING VITAMIN D_3 LEVELS UPON THE PERFORMANCE OF CHICKS RECEIVING CITRUS SLUDGE IN THEIR DIET[1]

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Abstract: *Supplemental vitamin D_3 levels of 200, 400, 800 and 1600 ICU and sludge levels of 0, 5, 10 and 15% were fed in 2 experiments to broiler chicks (age 1-21 da) to determine if iron or other heavy metals contained in the sludge destroyed vitamin D_3 and depressed performance. Adding vitamin D_3 to the diet did not offset the depressing effect of sludge feeding upon body weight. Tibia ash data were not significantly influenced by adding sludge. The highest level of vitamin D_3 supplementation did significantly improve tibia ash. We conclude that the adverse effects of sludge addition were not related to vitamin D_3 destruction.*

Citrus sludge results from the cleaning procedures for waste water from citrus processing plants. Plants using activated sludge treatment usually route the waste stream first to a large tank where initial medium aeration occurs. This tank serves to initiate the process and regulate the day-to-day consistency of the load. Next, the waste flows to a second tank where vigorous aeration occurs. Significant culture growth and production of sludge occurs. The effluent then goes to a clarifier, allowing the sludge to settle and be removed. Usually a portion of the sludge is recycled back into the system, with excess sludge being pumped off and recovered by sand filtration, centrifugation or other means (Kesterson and Braddock, 1976). Sludge contains proteinaceous material formed by microbial action in both aerobic and anerobic digestion systems (R. Coleman and D. Shaw, pers. comm.). An estimated 3.86 million kg/yr of citrus sludge are produced in the United States (U.S. Department of Agriculture, 1975). Jones et al. (1975) studied the cost of dewatering citrus sludge and proposed that dried sludge be formulated into poultry diets.

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Published literature concerning citrus sludge as an animal feed ingredient is limited. Most literature is on sewage sludge which is a similar product and produced on a much larger scale.

Activated sewage sludge is a good source of vitamin B_{12}. Feeding trials indicate that 2% sludge provide a satisfactory level of vitamin B_{12} for the pig (Schendel and Johnson, 1954). Similar studies by Hurwitz (1957) with chicks demonstrated that as little as 1% sludge furnished an adequate amount of vitamin B_{12} for growth. Levels up to 3% gave an additional response which could not be attributed to the vitamin B_{12} alone and was felt to indicate the presence of unidentified growth factors.

Firth and Johnson (1955) found that dry activated sludge was included up to 5% in the diet of the baby pig without adverse effects on growth and levels of 2 and 10% in the diet of the chick produced more than an 8% growth response when compared to the control group.

Dry sludge obtained from citrus waste waters by the activated sludge process was shown by Dougherty and McNary (1958) to contain between 28.9 and 43.8% protein, to have significant quantities of the B group vitamins and to be a particularly good source of B_{12}.

Damron et al. (1976) reported that including up to 10% citrus sludge in the diet did not significantly affect chick body weights after 3 wk; however, birds fed citrus sludge at levels of 15 and 20% were significantly lighter than controls. They also found that when citrus sludge was fed to broilers at 2.5, 5, and 10% for 8 wk, no significant differences were found among final body weight means. Body weights increased through the 5% level of supplementation with the weights of the birds receiving 10% sludge being lower than those of controls.

Hurwitz (1957) noted symptoms of rickets in chicks fed a commercial feed mixture in which activated sludge was included at levels of 2.5 and 5% to replace vitamin B_{12}, fish meal and meat meal. Vitamin D_3 had been added to these diets at the rate of 220 ICU/kg. Hurwitz concluded there could have been many possible causes for the development of rickets; however, the most obvious one was that iron and other heavy metals in the sludge destroyed the vitamin D_3. Our study was initiated to determine if growth depression, associated with the higher levels of citrus sludge, could be due to the destruction of vitamin D_3.

SLUDGE PROCUREMENT AND DRYING—Approximately 1000 kg of dried citrus sludge (11.1% moisture) were obtained from Citrus World, Inc. of Lake Wales, Florida through the recovery scheme discussed below.

Effluent was pumped from the sump of the first clarifier with a progressing cavity pump set to deliver approximately 132.5 1/min to a Sharples-

Stokes batch-type basket centrifuge (Model SP-5500). The centrifuge was equipped with a 60-horsepower motor powering a variable speed hydraulic drive assembly generating a centrifical force of 1300 Gs. The unit was mounted on a trailer and equipped for full automatic operation on a uniform time cycle. An automatic skimmer attachment skimmed the cake to uniform thickness before it was plowed into the discharge basin. The resulting material contained about 7% solids at this processing stage.

The sludge was placed into drums and hauled to the Department of Poultry Science at Gainesville for additional drying. Drying was accomplished by spreading the sludge on the floor of a windowless room with a sloping concrete floor. A small, commercial gas-fired crop dryer controlled by a central thermostat set at 32°C provided and circulated dry heat. The sludge was stirred several times daily with a large wooden rake.

When the product was solid enough to be ground (friable to the touch) it was passed through a 20.3 cm hammermill without a screen, producing a particle size of approximately 0.63 cm in dia. Final drying to a moisture content of approximately 11.1% was accomplished on a small plywood drying bed under electric heat lamps. The sludge was then stored in plastic-lined burlap bags at 14°C. Before mixing into feeds, it was passed through a small-mesh screen in a hammermill.

EXPERIMENTAL PROCEDURE—As a basis for feed formulation, a proximate analysis (Table 1) was conducted by the Florida Department of Agriculture and Consumer Services at Tallahassee. To examine the metals present a sludge example was also submitted to Law and Company, Atlanta, Georgia, a commercial analytical laboratory (Table 2).

Because citrus crops are often treated with pesticides that could be carried through to the processing plant and waste water, the Florida State Pesticide Residue Laboratory at Tallahassee performed a routine screening analysis (Table 3). The residues were found to be well within normal levels and were not felt to be a potential hazard.

In each of 2 experiments, a graded series of supplemental vitamin D_3 levels (200, 400, 800, and 1600 ICU/kg) and sludge levels of 0, 5, 10 and 15% were fed in a corn-soy basal diet (Table 4) to broiler-type (Cobb) chicks from 1-21 da of age. These diets were formulated with equivalent levels of nutrients through the use of data in Table 1. Four replicate pens containing

TABLE 1. Proximate analysis of citrus sludge.

Nutrient	Percent
Moisture	11.10
Crude Protein	22.35
Fat	7.40
Fiber	11.45
Ash	12.20
Calcium	1.60
Phosphorus	0.45

TABLE 2. Trace mineral analysis of citrus sludge.

Element	Content (ppm)*
Aluminum	2500
Cadmium	1
Chromium	100
Cobalt	3
Copper	260
Iron	4600
Lead	120
Magnesium	2100
Manganese	51
Mercury	0.5
Nickel	120
Potassium	7300
Selenium	1
Sodium	5300
Zinc	430

*Dry-weight basis.

TABLE 3. Pesticide residue analysis of citrus sludge.

Pesticide	Content (ppm)
Ethion	1.88
Dicofol	1.00
Screen—Chlorinated compounds	0
Screen—Phosphorus compounds	0

TABLE 4. Diets containing graded levels of citrus sludge to which varying amounts of vitamin D_3 were added.

Ingredients	Percent Sludge:	0	5	10	15
Yellow corn		53.00	48.83	44.65	40.52
Soybean meal (49%)		38.00	36.34	34.67	32.80
Citrus sludge		-------	5.00	10.00	15.00
Limestone		0.31	0.34	0.35	0.33
Dicalcium phosphate (18% P & 24% Ca)		3.26	3.22	3.26	3.30
Iodized salt		0.40	0.40	0.40	0.40
Microingredients*		0.50	0.50	0.50	0.50
Animal fat		4.42	5.22	5.95	6.81
DL-Methionine		0.11	0.15	0.19	0.24
L-lysine		-------	-------	0.02	0.10

*Ingredients supplied per kg of diet: Vitamin A, 6600 IU; vitamin D_3, 2200 ICU; menadione dimethylpyrimidinol bisulfite, 2.2 mg; riboflavin, 4.4 mg; pantothenic acid, 13.2 mg; niacin, 39.6 mg; choline chloride, 499.4 mg; vitamin B_{12}, 22 mg; ethoxyquin, 0.0125%; manganese, 60 mg; iron, 50 mg; copper, 6 mg; cobalt, 0.0198 mg; zinc, 35 mg.

TABLE 5. Two-way summary of 21-da body weight data from chicks that received various levels of citrus sludge and vitamin D_3.

Supplemental Vit. D_3 level	Sludge Level (% of diet)				
(ICU/kg)	0	5	10	15	Mean*
			Experiment 1		
200	541	532	501	492	517^{ab}
400	527	574	520	410	508^{b}
800	531	566	536	484	529^{a}
1600	533	541	542	480	524^{ab}
Mean*	533^{b}	553^{a}	524^{b}	466^{c}	
			Experiment 2		
200	536	535	495	490	514^{ab}
400	539	535	500	471	511^{b}
800	537	545	533	499	528^{a}
1600	509	538	520	479	512^{b}
Mean*	530^{ab}	538^{a}	512^{b}	485^{c}	

*Means without common letters are significantly different according to Duncan's multiple range test ($P<.05$).

8 birds each (4 males and 4 females) received each dietary treatment. The chicks were grown in electrically-heated Petersime battery brooders with raised wire floors. Records were kept for body weight, feed consumption, mortality, and general condition of the birds.

Tibia ash values were determined for 2 birds of each sex from each pen. The entire tibia from the left leg of each bird was weighed, placed in a tared crucible, ashed at 650°C for 5 hr and then allowed to cool in a desiccator. The samples were then reweighed and ash values determined.

All data obtained were statistically analyzed by computer using analysis of variance and Duncan's multiple range test (Barr et al., 1976).

RESULTS AND DISCUSSION—A significant treatment by experiment interaction was found among body weight data; therefore, the 2 experiments have been analyzed separately (Table 5). There was little difference in body weight in both experiments when expressed by levels of D_3, although chicks receiving 400 ICU were significantly lighter than those receiving 800 ICU. When body weight was expressed on the basis of sludge addition, there was a significant depression at the 15% level in both experiments; the highest numerical body weight was at the 5% sludge level in both experiments and was significantly higher than the control diet of experiment 1.

There was a significant interraction between citrus sludge and vitamin D_3 in the daily feed intake data (Table 6). It is believed that the significance was largely due to the depressed value associated with 400 ICU of vitamin D_3 and 15% citrus sludge. We cannot explain this value because a similar sludge treatment with less vitamin D_3 (200 ICU) did not produce such a

TABLE 6. Daily feed intake of chicks that received various levels of citrus sludge and vitamin D$_3$*.

Supplemental Vit. D$_3$ level (ICU/kg)	Sludge Level (% of diet)				
	0	5	10	15	Mean**
200	36.99	37.26	37.11	36.81	37.04^{b}
400	37.64	36.43	37.30	34.20	36.39^{b}
800	37.73	37.60	37.69	37.84	37.71^{ab}
1600	38.13	37.76	38.55	40.39	38.71^{a}
Mean**	37.62^{a}	37.26^{a}	37.66^{a}	37.31^{a}	

*Values are a combination of 2 experiments.

**Means without common letters are significantly different according to Duncan's multiple range test ($P<.05$).

response. As the level of vitamin D$_3$ increased feed intake increased, with the 1600 ICU level being significantly higher than the 200 and 400 ICU treatments. Citrus sludge had no significant effect on feed intake.

Contrary to the supposition advanced as an objective at the beginning of this study, increasing levels of dietary citrus sludge did not affect tibia ash values (Table 7). Feed efficiency decreased significantly at both the 10 and 15% sludge levels. Vitamin D$_3$ additions did not influence feed efficiency (Table 7). Tibia ash values increased numerically as the level of vitamin D$_3$ increased, with the 200 and 1600 ICU levels being significantly different from each other.

There were no significant differences in mortality due to levels of vitamin D$_3$ (Table 8). There were significant differences among sludge treatments; however, the data did not appear to be associated with increasing citrus sludge additions to the diet.

In summary, the depressing effect that sludge had on body weight was not improved by adding vitamin D$_3$ to the diet of the chick. The cause of depressed body weight by sludge was probably not due to the destruction of vitamin D$_3$ by the high level of iron in sludge as was suspected by Hurwitz (1957).

TABLE 7. Tibia ash and feed efficiency of chicks summarized by main effects after feeding various levels of citrus sludge and vitamin D$_3$*.

Sludge Level (%)	Tibia Ash (%)	Feed/Body Wt (g/g)	Supplemental Vit. D$_3$ Level (ICU/kg)	Tibia Ash (%)	Feed/Body Wt (g/g)
0	45.35^{a}	1.48^{c}	200	45.19^{b}	1.52^{a}
5	45.38^{a}	1.47^{c}	400	45.43^{ab}	1.53^{a}
10	45.80^{a}	1.55^{b}	800	45.54^{ab}	1.52^{a}
15	45.43^{a}	1.62^{a}	1600	45.80^{a}	1.55^{a}

*Means without common letters are significantly different according to Duncan's multiple range test ($P<.05$). Values are a combination of 2 experiments.

TABLE 8. Mortality of chicks summarized by main effects after feeding various levels of citrus sludge and vitamin D_3*.

Sludge Level (%)	Mortality (%)	Supplemental Vit. D_3 Level (ICU/kg)	Mortality (%)
0	1.56^{ab}	200	1.17^{a}
5	3.90^{a}	400	1.17^{a}
10	$.78^{b}$	800	3.90^{a}
15	2.73^{ab}	1600	2.73^{a}

*Means without common letters are significantly different according to Duncan's multiple range test ($P < .05$). Values are a combination of 2 experiments.

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CHARACTERISTICS OF RED-COCKADED WOODPECKER CAVITY TREES AND COLONY AREAS IN SOUTHERN FLORIDA

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Abstract: *Cavity tree and vegetative characteristics of red-cockaded woodpecker* (Picoides borealis) *colonies from 5 wildlife management areas in southern Florida are summarized. On the average, trees utilized for cavity excavation were shorter, smaller in dbh, older, and more widely-spaced than elsewhere in the species' range. Cavities were most commonly found in slash pines (*Pinus elliottii var. densa*). Colony areas were sparsely stocked, with little or no midstory. Poor growth conditions, extensive timber harvesting and historic timber management practices explain the current condition of red-cockaded woodpecker nesting habitat in this area.*

Because the red-cockaded woodpecker (*Picoides borealis*) was listed as endangered in 1970 (FR35:16047), many researchers have dealt with both cavity tree and vegetative characteristics in colony areas (e.g., Baker, 1971; Crosby, 1971; Hopkins and Lynn, 1971; Ligon, 1970; Lennartz et al., 1976; Thompson and Baker, 1971; Van Balen and Doerr, 1978; Wood, 1975; and Wood, 1976). However, except for a recent project in the Big Cypress National Preserve (Patterson and Robertson, 1981) none of those studies addressed habitat parameters for red-cockaded woodpecker colonies occurring in southern Florida, where this bird is more widespread and abundant than previously reported (Baker et al., 1980). Through independent surveys and a statewide inventory initiated by the Florida Game and Fresh Water Fish Commission in 1978, at least 80 colonies have been located on public and private lands from Orlando southward into the Big Cypress National Preserve. Many areas remain unsurveyed. Cursory investigations suggest that red-cockaded woodpecker colony habitats in south Florida may differ from sites elsewhere. Two primary goals of the Red-cockaded Woodpecker Recovery Plan are to identify and then to protect extant populations (Jackson et al., 1979). To successfully achieve these goals, it is essential that suitable red-cockaded woodpecker colony sites be accurately described. I summarized data collected thus far on red-cockaded woodpecker cavity trees and colony areas in selected portions of southern Florida.

Methods and Study Areas—Cavity tree data (species, distance to nearest cavity tree, active cavity trees per colony, age, tree height, dbh, cavity orientation, cavity height, number of cavities per tree) were collected between 1978 and 1980 by Florida Game and Fresh Water Fish Commission personnel and U. S. National Park Service employees on the following Wildlife Management Areas (WMAs): Avon Park, J. W. Corbett, Cecil M. Webb, Three Lakes, and Big Cypress. Start holes were omitted from analyses, except when calculating distance to nearest cavity tree. Certain cavity tree data were analyzed for particular species: longleaf (*Pinus palustris*), slash (*P. elliottii var. densa*), and mixed (longleaf, slash, loblolly, *P. taeda*, and pond, *P. serotina*) pines.

To collect habitat data, quadrats of 30.5 m x 30.5 m were established with selected cavity trees at the center of each plot, if possible. Average vegetative height, stem density, basal area (BA), diameter at breast height (dbh) of the overstory and midstory vegetation (where applicable) were then determined by random sampling. Habitat data were not collected on Big Cypress WMA.

Locations of the 5 WMAs surveyed are in Fig. 1. The Cecil Webb WMA consists of 25,312 ha in Charlotte County. A very significant percentage of the land on the Webb is southern slash pine (average BA is 4.7 m^2/ha), with an understory of saw palmetto (*Serenoa repens*), wiregrass (*Aristida stricta*), wax myrtle (*Myrica cerifera*), huckleberry (*Cyanococcus myrsinites*), *Rhyncospera* sp. and *Xyris* sp. Prior to acquisition by the Florida Game and Fresh Water Fish Commission in the 1940s, timber was extensively harvested there. Thousands of hectares now have virtually no tree cover and, as a result, little chance to naturally reforest. This management area generally lacks a diversity of age groups, with relatively few young and few old trees.

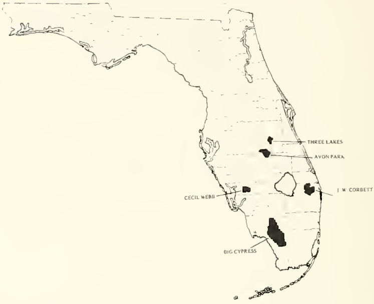

FIG. 1. Five south Florida Wildlife Management Areas surveyed for red-cockaded woodpecker colonies.

The 22,680 ha J. W. Corbett WMA is located in the northwest portion of Palm Beach County. In general, the history of timber harvesting on the Corbett is similar to that of the Webb. However, the Corbett WMA has a greater diversity of age groups, relatively higher tree density and better pine regeneration than the Webb WMA.

Three Lakes WMA is a 17,313 ha tract in south-central Osceola County. Approximately 6,651 ha is comprised of longleaf pine flatwoods, with an understory and midstory characterized by saw palmetto, *Lyonia*, *Ilex*, scrub oak (*Quercus* sp.) and wiregrass. A small percentage of the area is slash pine flatwoods with an understory commonly composed of saw palmetto, *Ilex* and wax myrtle. Approximately 60% of Three Lakes was virgin longleaf pine forest prior to the 1920s, with an average BA of 9.2-13.8 m^2/ha. Much of the area was logged after the 1920s. After timbering, natural reproduction was restricted by frequent and untimely burning and lack of available seed trees. Many areas now contain only 2.5-5 pines/ha.

Avon Park WMA is an Air Force Bombing Range in Polk and Highlands counties. Most of the area, 23,085 ha, is typical south Florida mixed longleaf and slash pine flatwoods interspersed with small swamps and wet prairies. Before 1951, uncontrolled timber harvesting and burning were common. Beginning in 1965, 10,935 ha were reforested with slash pine; 1,620 ha are currently stocked with 33-45 yr-old slash pine. The remainder is virtually unstocked, with saw palmetto, *Ilex* and grasses as the primary cover. A 3,807 ha sand ridge runs north-south through the WMA. It is comprised of 15-45 yr-old sand pine (*P. clausa*), open scrub oak with scattered longleaf, and 45-65 yr-old longleaf pine stands. Stands average 4.7 m^2/ha and 49 pine stems/ha.

The Big Cypress WMA is a 230,280 ha tract situated in Collier, Dade and Monroe counties. This WMA shares the common boundary with Big Cypress National Preserve. The population of red-cockadeds in the Big Cypress represents the southern limit of this species' range. Pinelands occupy a variety of sites, from the seldom inundated sandy soils at the northern extreme to frequently flooded marl soils interspersed with cypress (*Taxodium distichum*) or prairies containing *Aristida* sp., beakrush (*Rhyncospera* sp.), muhly grass (*Muhlenbergia* sp.), saw palmetto, cabbage palm (*Sabal palmetto*) and wax myrtle. Relict forest patches in cut-over areas exist in western part of the Big Cypress and unlogged (virgin) pine islands occur north and northeast of the main interior pineland section. Much of the WMA pine forest has been frequently burned.

RESULTS AND DISCUSSION—Forty-nine colonies surveyed averaged 2.3 active cavity trees per colony (range = 1-7). Thompson and Baker (1971) reported an average of 4.0 active cavity trees per colony in 229 colonies scattered throughout 10 southeastern states. Average minimum distance between cavity trees within colonies was 104.0 m (N = 48 colonies). Average distances per colony ranged from 17 to 805 m. Wood (1975) found that, in Oklahoma, minimum distance between cavity trees within a colony averaged 58 m (range = 5-240 m), Hooper et al. (1980) reported that distance varies from 9.0 m to 800 m rangewide, and Hopkins and Lynn (1971) found that trees in colonies in South Carolina averaged 64.0 m (range = 10.0-342.0 m) apart.

Cavity tree orientation data were collected for a total of 401 active or once-active cavities. Of those, 68% faced in a predominantly westerly direction; 38% southwest, 15% west, and 15% northwest (Fig. 2). This is consistent with the orientation of cavities found elsewhere in the red-cockaded woodpecker's range (Baker, 1971; Dennis, 1971; Hopkins and Lynn, 1971; Lay and Swepston, 1973; Carter, 1974).

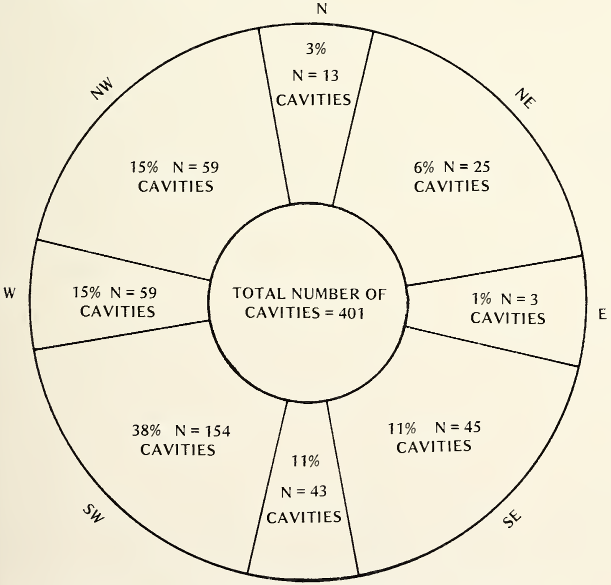

FIG. 2. Orientation of south Florida red-cockaded woodpecker cavities.

TABLE 1. Characteristics of red-cockaded woodpecker cavity trees in south-central and south Florida and elsewhere in the literature.

	South Florida			Literature		
Parameter	Longleaf	Slash	Mixed	Longleaf	Slash	Mixed
dbh (cm)						
$\bar{x}$	32.1	33.8	27.9	39.4	40.6	43.7
N	133	168	42	770	15	729
Range	20.8-48.3	22.3-51.4	20.3-33.8	----	----	----
Source[1]	----	----	----	4,5,7	7	2,5
Height (m)						
$\bar{x}$	13.5	15.3	15.9	21.7	25	20.5
N	139	169	42	764	15	723
Range	6.7-24.1	2.7-30.2	8.8-28.0	----	----	----
Source[1]	----	----	----	4,5,7	7	2,5
Age (years)						
$\bar{x}$	103.5	102.7	109.5	86	70	84
N	105 (+ 8 heartrot)[2]	91 (+20 heartrot)[2]	39 (+ 3 heartrot)[2]	610	15	627
Range	55-142	57-182	80-137	----	----	----
Source[1]	----	----	----	3	3	3
Cavity Height (m)						
$\bar{x}$	4.9	7.8	6.4	7.4	No Data	7.9
N	156	191	45	70	----	1,164
Range	1.4-9.1	1.8-21.7	2.7-12.2	----	----	----
Source[1]	----	----	----	1,5,6	----	2,5
Cavities/Tree						
$\bar{x}$	1.1	1.2	1.3	1.01	1.0	1.6
N	145	165	42	560	15	815
Source[1]	----	----	----	7	7	2

[1] 1 = Baker, 1971; 2 = Carter, 1974; 3 = Wood, 1975; 4 = Hopkins and Lynn, 1971; 5 = Lay and Swepston, 1973; 6 = Ligon, 1970; 7 = Thompson and Baker, 1971.

[2] Trees with heartrot could not be aged.

Cavity tree parameters are summarized by species in Table 1. Characteristics of trees elsewhere in the southeast, as reported in the literature, were included for comparison. In southern Florida, approximately 48% of the trees for which data were collected was slash pine (N = 168), 40% was longleaf pine (N = 139) and the remaining 12% (N = 42) was mixed species. All cavity trees on the Corbett, Webb and Big Cypress WMA's were slash pines.

All species of cavity trees were shorter, older and smaller in dbh, on the average, than elsewhere in the southeast (Table 1). The most obvious explanation for this is the poor site quality of these south Florida flatwoods. The observed older age of the south Florida cavity trees as compared to other areas supports this explanation. On poor sites, it takes trees longer to grow to a diameter large enough to permit cavity excavation (Thompson and Baker, 1971). Data on cavity tree ages in the Big Cypress WMA were not available but those trees are as old or older than trees aged on the other WMAs (D. Pylant and M. Robson, pers. comm.). South Florida cavities were generally lower than cavities found elsewhere in the Southeast, ranging from 1.4-9.1 m for longleaf, 1.8-12.5 m for slash and 2.7-12.2 m for mixed species (Table 1).

As is summarized in Table 2, a typical colony in southern Florida has a very sparsely stocked pine overstory and generally lacks a midstory (76% of 150 plots had no midstory). The average height and dbh of the overstory was lower than that of cavity trees, suggesting that those trees utilized by the woodpeckers for roosting and nesting were often the dominant trees within the colony area. This may have been an artifact of past logging activities.

Red-cockaded woodpecker colonies in southern Florida are found in older or the oldest, sparsely stocked pine stands. The comparatively smaller height and dbh and older age of individual cavity trees appear to be a function of poor growth conditions. On the average, cavity trees were more widely spaced than cavity trees found farther north. This is doubtless due to the lower BA and stem density that resulted from poor growth conditions, previous extensive timber harvesting and historic timber management prac-

TABLE 2. Characteristics of the vegetation surrounding red-cockaded woodpecker cavity trees in south Florida.

Parameter	Overstory	Midstory
Average height (m)	11.04	2.7
N	131	36
Average d.b.h. (m)	23.0	5.3
N	125	13
Average density (stems/ha)	10.5	4.0
N	120	12
Average basal area (m²/ha)	4.0	-
N	105	-

tices on these areas. These habitat and cavity tree characteristics may not represent optimal, historic habitat conditions for south Florida colonies but they are representative of the sort of habitat available to these birds at present. Management of southern Florida colonies should therefore be designed to promote regeneration and encourage establishment of the more densely-stocked pine stands that occurred historically on those areas.

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Biological Sciences

ESCAPE RESPONSE OF *ARGOPECTEN IRRADIANS* (MOLLUSCA: BIVALVIA) TO *LUIDIA CLATHRATA* AND *ECHINASTER* SP (ECHINODERMATA: ASTEROIDEA)

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Abstract: *The bay scallop* (Argopecten irradians) *showed a strong escape response when placed in contact with the asteroid* Luidia clathrata. *This response is characterized by rapid movements of the valves resulting in immediate displacement of the asteroid and subsequent relocation of the bivalve. The scallop demonstrated only minimal levels of response when placed in contact with the asteroid* Echinaster *sp. Whole animal homogenates of the 2 asteroid species injected into the mantle cavity of* A. irradians *resulted in similar patterns of response. The intensity of the escape response elicited by* A. irradians *may be related to the different feeding modes of these 2 asteroid species.* Luidia clathrata *feeds primarily on macrofauna (e.g., bivalves, ophiuroids, and polychaetes), while* Echinaster *sp feeds primarily on detritus and encrusting organisms.*

Escape responses of molluscs from asteroids have been well-documented (for reviews see: Bullock, 1953; Kohn, 1961; Feder, 1963; Margolin, 1964a; Feder and Christensen, 1966). However, most studies have been confined to temperate systems; Feder (1967) has emphasized the need for further studies in other areas. Predator avoidance and escape mechanisms of animals have obvious implications in structuring communities. Asteroids are efficient predators (Menge, in press) and may affect prey abundance and distribution. Escape responses function in preventing predation by asteroids to varying extents (Feder, 1963; Margolin 1964b; Feder, 1967). In most cases these prey show a well-developed ability to recognize their specific predators (Feder, 1972).

The escape response of scallops to asteroids was first noted in *Pecten jacobaeus* exposed to "seastar skin extract" (Dakin, 1910; Bauer, 1912, 1913). Uexküll (1912) observed a strong "flight" response of *Pecten maximus* when touched by *Marthasterias glacialis*. Lecompte (1952) found the strongest escape response of *Pecten maximus* and *P. jacobaeus* to 5 asteroid species was elicited when scallops were placed in contact with *M. glacialis*, a natural predator. *Asterias rubens* elicits a strong escape response in *Pecten* spp (Feder, 1967). This escape response is characterized by swimming by rapidly opening and closing the valves. There is a definite lack of directionality, but the behavior seems to be effective in preventing extensive predation (Feder, 1967).

The bay scallop *Argopecten irradians* (Lamarck) is distributed from New England to Mexico. It is a common inhabitant of shallow waters of bays and estuaries. The asteroid *Luidia clathrata* (Say) is distributed widely along the Atlantic Coast from New Jersey to Brazil in 0-75 m depth. *Luidia clathrata* is a highly mobile, soft-bottom predator which feeds on infauna (Lawrence and Dehn, 1979; McClintock and Lawrence, 1981). *Echinaster* spp occur in the tropical and subtropical Atlantic (Downey, 1973). The species of *Echinaster* investigated in this study is found on the West Coast of Florida and is referred to as *Echinaster* Type 1, which is characterized as orange-brown in color with an average maximum size of 10 cm (Scheibling, 1982). This asteroid inhabits soft-bottom marine substrates where it is primarily a microphagous feeder.

I discuss the escape response of the bay scallop to these 2 asteroid species which show different feeding behaviors. In addition, I provide information on mollusc-asteroid interactions in a subtropical-temperate ecotone.

METHODS—*Argopecten irradians* were collected in July 1981 from the Gulf of Mexico near Tarpon Springs, Florida in 2 m depth. *Luidia clathrata* and *Echinaster* sp were collected in July 1981 from Tampa Bay, Florida in 2-3 m depth. Animals were maintained without food in separate 15 l aquaria (25°C and 30 ppt) for 1 wk prior to experimentation.

The escape response of the scallop was investigated both with respect to physical and chemical stimuli. Physical contact experiments were performed by introducing a single *Argopecten irradians* (mean length 5.7 ± 1.0 cm) into an aquarium, allowing for a 5 min adjustment period, and then placing an asteroid directly onto the dorsal valve. Individuals of both asteroid species were of similar size (*Luidia clathrata* = 5.0 ± 1.2 cm radius; *Echinaster* sp = 4.2 ± 0.7 cm radius). The level of response was divided into the following categories: 0- no response, 1- opening of valves, 2- single clap of valves, and 3- multiple clapping of valves. Both the level of response and the amount of time spent in contact with the bivalve were recorded. Fifteen individuals of *A. irradians* were tested for escape responses with each asteroid species.

The response of the scallop to chemical stimulation was investigated by a modification of the methods of Margolin (1964a). Whole asteroids were homogenized in a blender with an equal volume of seawater (1 g wet tissue/1 ml seawater). The homogenate was diluted to concentrations of 10^{-6}, 10^{-5}, 10^{-4}, and 10^{-3} g wet tissue/ ml seawater. One ml of diluted homogenate was injected near the opening of the mantle cavity and the level of response was recorded for 5 min. Ten individuals of *Argopecten irradians* were tested at each concentration with each asteroid species. A control was conducted by injecting 1 ml of seawater near the mantle cavity of 10 *A. irradians*.

RESULTS—*Argopecten irradians* showed significantly ($P<0.01$; Student's t test) higher levels of response when placed in contact with *Luidia clathrata* than with *Echinaster* sp (Fig. 1). Multiple clapping was observed 86% of the time when scallops were placed in contact with *L. clathrata*. In contrast, no response was observed 86% of the time when scallops were placed in contact

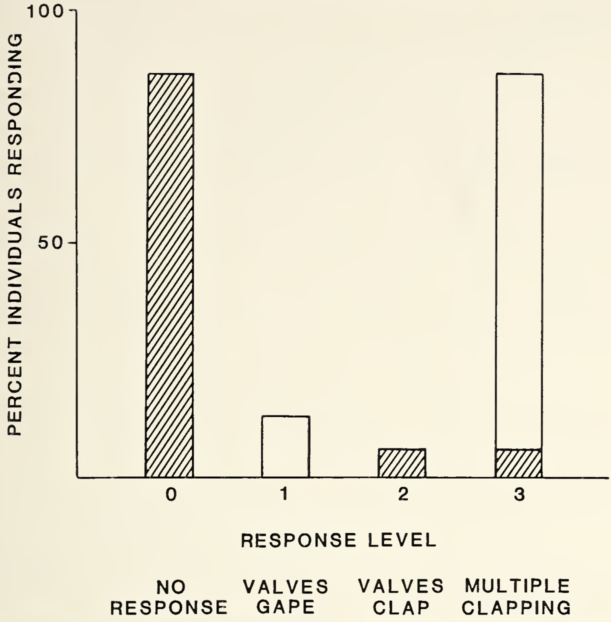

Fig. 1. Percent of *Argopecten irradians* showing levels of response to *Luidia clathrata* (open bars) and *Echinaster* sp (closed bars). (n = 15 for each treatment).

with *Echinaster* sp. The average time spent in contact with *L. clathrata* and *Echinaster* sp was 49 sec ± 29 sec and 12 min 4 sec ± 13 min, respectively.

The results of the chemical stimulation experiment were similar to the contact experiments (Fig. 2). No response was observed with injection of extracts of either asteroid species at concentrations of 10^{-6} g wet wt/ml seawater. However, there were significantly ($P < 0.05$; confidence intervals) higher levels of response recorded for *Luidia clathrata* at concentrations of 10^{-5}, 10^{-4}, and 10^{-3} g wet wt/ml seawater. Injection of seawater into the mantle cavity elicited no response by the scallops.

Discussion—*Argopecten irradians* elicited marked differences in level of escape response when exposed to *Luidia clathrata* and *Echinaster* sp. Individuals usually became active within 1 min when *L. clathrata* was placed onto the dorsal valve of the scallop. The "swimming" response effectively removed the asteroid from the dorsal valve. Swimming resulted in random displacement of the bivalve; distance of displacement was limited by the confines of the aquarium. I observed the scallop in the field to swim approximately 3 m, an adequate distance to prevent predation by *L. clathrata*.

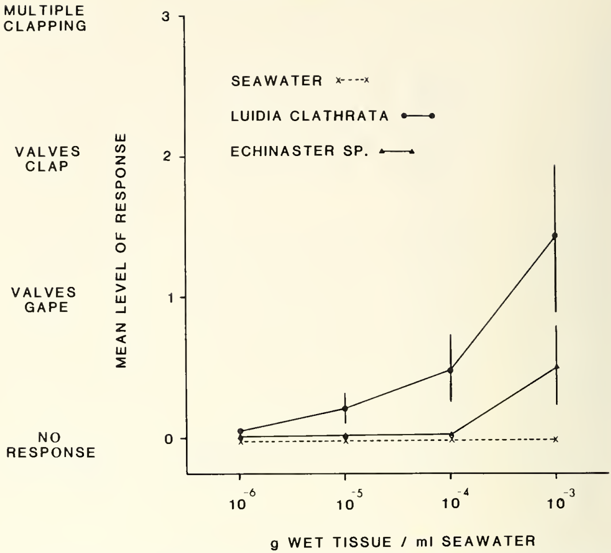

FIG. 2. Mean level of response ±1 S.E. of *Argopecten irradians* exposed to homogenates of whole *Luidia clathrata* (circles), *Echinaster* sp (triangles), and seawater control (dashed line). (n = 10 for each treatment).

Other species of *Luidia* cause similar escape responses in mollusks. *Luidia alternata* (5 cm radius) caused an immediate flipping response when placed in contact with the marine snail *Nassarius vibex* (Gore, 1966). Flipping removed the snail 25-30 cm from the starfish.

Luidia clathrata were unable to successfully feed on the scallop in the laboratory. This may be related to the combined effect of the escape response and the large size of adult *A. irradians* relative to adult *L. clathrata*. Members of the genus *Luidia* are intraoral feeders (Hyman, 1955) and therefore morphologically limited to prey that can be ingested. Adult *L. clathrata* prefer prey models less than 2 cm in diameter (McClintock and Lawrence, 1981). Although bivalves may attain a refuge in size (Paine, 1976), *L. clathrata* may be a significant predator of scallops of small size when available. In Tampa Bay, *L. clathrata* feeds primarily on bivalves (Lawrence et al., 1974). In the laboratory I observed them ingesting up to 33 bivalves (*Donax variabilis*; mean length 1 cm) within 1 hr (McClintock and Lawrence, unpubl.). Asteroids cause mortality among scallop populations. Dickie and Medcof (1963) attributed up to 25% of mortality of *Placopecten magellanicus* in the Southwest Gulf of Saint Lawrence to *Asterias vulgaris*.

The scallop showed very low levels of escape response when placed in contact with *Echinaster* sp. In several instances, starfish spent over 1 hr on the surface of the valve with no apparent affect on the bivalve. Similarly, *Pecten jacobaeus* and *P. maximus* showed minimal escape responses from *Echinaster sepositus* (Lecompte, 1952). *Nassarius vibex* showed no flipping response when placed near *Echinaster sentus* (Gore, 1966). In contrast to *Luidia* spp, members of the genus *Echinaster* are relatively sluggish. Individuals of *Echinaster* sp may not be able to capture *A. irradians*. *Echinaster* sp are considered omnivorous, microphagous grazers and opportunistic predators and scavengers of sessile macrofauna, primarily sponges and ascidians (Ferguson, 1969; Scheibling, 1982). This feeding mode suggests an inability to feed on juvenile or adult scallops. However, the possibility of feeding on recently-settled veliger larvae cannot be excluded.

Injections of different concentrations of starfish homogenate into the mantle cavity supported the observation that the scallop showed a stronger escape response to *Luidia clathrata* than to *Echinaster* sp. The level of response was not as strong as that elicited by physical contact with the starfish. This suggests that the escape response of *A. irradians* is probably dependent upon a synergistic interaction of physical and chemical stimuli. Such graded responses have been observed in other mollusc-asteroid encounters. Hoffman (1981) found that trochid gastropods elicited only a weak response to the scent of *Leptasterias hexactis*, while contact elicited a strong and violent response.

The scallop may become desensitized to the presence of starfish. Swimming behavior by *Argopecten irradians* was frequently observed when *Luidia clathrata* were initially placed into an aquarium. The bivalves returned to a more quiescent state after several hours. Margolin (1964a) also found that repeated stimulation of the limpet *Diodora aspera* to *Pisaster ochraceus* resulted in a decrease in starting reaction time for the second and third stimulation, and complete cessation of response after 320 to 390 min.

Molluscs may respond only to predatory starfish (Bullock, 1953; Yarnell, 1964; Edwards, 1969; Phillips, 1976). My results suggest that *Luidia clathrata* and *Echinaster* sp impose different levels of predation upon populations of the scallop *Argopecten irradians*. The escape response of *A. irradians* may decrease predatory pressure by *L. clathrata* during the juvenile stage, allowing individuals to attain a refuge in size.

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COMPARISON OF LITTER FALL AND TURNOVER IN TWO FLORIDA ECOSYSTEMS

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Abstract: *Sand pine and sandhill forests were compared with regard to the rates of litter-fall, litter standing crop, and litter turnover. Litter-fall rates in the sand pine and sandhill were low (330 and 278 g/m²•yr, respectively), litter standing crop was high (averaging 1367 and 842 g/m², respectively), and litter turnover rate was low (0.21 and 0.33 times/yr, respectively). These results and the simple structure of the forests were attributed to the extreme harshness of their respective environments (low nutrient concentrations in soils, water stress, and fires). However, the pattern of litter-fall was different in the 2 forests, probably reflecting different responses to fire frequency and nutrient availability. The sandhill forest retained its leaves longer and dropped them over a longer time period than did the sand pine forest. Because fires are more frequent in sandhill environments and because the forest floor of sandhills is exposed to more wind than that of sand pine forests, it is suggested that this strategy of leaf retention is advantageous for maintaining nutrients within the ecosystem.*

Sandhills and sand pine forests are among the most stressed Florida terrestrial ecosystems, because they grow in sandy soils with low nutrient concentrations (Snedaker, 1973; Veno, 1976), are exposed to long periods of drought due to the sandy nature of the soil, and suffer periodic setbacks due to fires. Previous studies in these forests include floristic descriptions (Mulvania, 1931; Laessle, 1942), and observations on succession (Laessle, 1958; Snedaker, 1963; Monk, 1960, 1968; and Veno, 1976). Results for both forest types document the slow rates of succession, simplicity of vegetation structure, and the harshness of the environment. In this study we compare litter-fall rates and litter turnover in these ecosystems.

Description of Ecosystems—The study sites were located in the Ocala National Forest (29°14′N latitude, 1300 mm of annual rain, and mean annual temperature of 21°C), and in the San Felasco Hammock, just northwest of Gainesville (29°42′N latitude, 1275 mm of annual rain, and mean annual temperature of 21.1°C).

Sand Pine Forest—The sand pine (*Pinus clausa*) was by far the dominant tree species in the Ocala National Forest site (Table 1). Oaks, *Quercus laevis* and *Q. myrtifolia*, comprised the second most common group of tree species in terms of number of individuals; however, their contribution to the total basal area of the stand was insignificant. Sand pine individuals were not represented in the understory. The shrub understory was dominated by the oak, *Q. myrtifolia*.

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TABLE 1. Structural and floristic characteristics of a sand pine forest located in the Ocala National Forest. Data are based on 17 points (Cottam and Curtis, 1956).

Species	Basal Area m^2/ha	Density Individuals/ha	Frequency %	Importance Value (frequency, density, dominance)
Trees ($\geq$2.5 cm dbh)				
Pinus clausa	10.62	717	42	190
Quercus laevis	0.82	179	27	48
Quercus myrtifolia	0.38	251	18	42
Quercus chapmanii	0.08	35	6	10
Quercus geminata	0.02	18	3	5
Lyonia ferruginea	0.01	18	3	5
Total	11.93	1218	99	300
Shrubs ($<$2.5 cm dbh)				(frequency and density)
Quercus myrtifolia	22053	53	120	
Quercus geminata		2939	13	22
Sabal etonia		2449	10	17
Quercus chapmanii		1469	7	11
Vaccinium myrsiaites		979	7	10
Lyonia fruticosa		1469	3	8
Conradina sp.		979	3	6
Ceratiola ericoides		979	3	6
Total		33318	99	200

Complexity Index: (Maximum tree height) (Basal area in 0.1 ha) (Tree density in 0.1 ha) (Number of species) (10^{-3}) = 12.1.
Lichen cover: 32% (n = 10).
Canopy cover: 85% (n = 25, SE = 1.7).
Light transmission: 82% (n = 40).

The high transmission of visible light (82%) and relative openness of the sand pine canopy (15%) may account for the relatively high diversity of shrubs under the tree stratum (Table 1). Lichens (*Cladonia* sp.) covered 32% of the forest floor and no significant herbaceous layer was observed. In general, the stand had low vegetation complexity (a complexity index of 12, Table 1).

SANDHILL FOREST—The sandhill forest had only 2 tree species, the turkey oak (*Q. laevis*) and the long leaf pine (*P. palustris*). The structural simplicity of the forest was reflected on low basal area, low complexity index, and short canopy height (Table 2). The complexity of vegetation was a third lower than that of the sand pine forest (Table 2). The proportion of standing dead stems in the forest was negligible. As is typical of all sandhill forests, the stand was open and park-like in appearance with ground patches of open sandy areas that were litter-free. Mosses and lichen grew on the sandy, litter-free patches, while herbaceous plants predominated in the rest of the understory.

TABLE 2. Structural and floristic characteristics of trees (>2.5 cm dbh) on a sandhill forest located in the San Felasco Hammock in Gainesville, Florida.

Species	Basal Area m²/ha	Density Individuals/ha	Frequency %	Importance Value (frequency, density, dominance)
Quercus laevis				
live trees	9.1	1010	80	259
standing dead	0.5	255	--	--
Pinus palustris				
live trees	1.3	60	20	41
standing dead	0	5	--	--
Total for stand				
live	10.4	1070	100	300
dead	0.5	260	--	--

Complexity Index: (Maximum tree height) (Basal area in 0.1 ha) (Tree density in 0.1 ha) (Number of species) (10^{-3}) = 3.9.
Mean canopy height: 11.7 m.
Tallest tree: 18 m.

METHODS—Twenty 0.21 m² baskets were located along a 200 m transect through the sand pine forest for litter-fall determinations. They were collected 18 times on an irregular schedule between December 1970 and February 1973. Litter standing crop was determined from ten 0.25 m² plots that were harvested with each litter-fall collection. Litter-fall samples were dried to constant weight at 70°C, separated into leaves, wood, reproductive parts and miscellaneous, and weighed. Litter standing crop samples were dried to constant weight at 70°C, separated into wood, leaves and lichens, and weighed. Lichens, which grew on the forest floor, were not part of the dead litter compartment, but were collected to determine their cover and biomass.

Litter-fall in the sandhill forest was measured with twenty 0.25 m² baskets located along 3 transects throughout the study area. Litter was dried to constant weight at 70°C, separated into leaves (by species), wood, and miscellaneous, and weighed. When it was discovered that wind redistribution of ground litter could fill the collection baskets located on the forest floor, a new set of baskets was installed. These were elevated 1 m from the ground and outfitted with a bag-like bottom which prevented loss or gain of litter. Collections from baskets on the forest floor were continued to calculate the effect of wind blown litter.

Litter standing crop was measured by collecting the 0.25 m² random samples 15 times between January, 1977 and July, 1979. Samples were dried to constant weight at 70°C for 3 da, separated into wood and miscellaneous (including leaves), and weighed. After a control burn of the forest, an equal number of ground litter samples were collected from a nearby, unburned forest.

RESULTS

Sand Pine Forest: The mean annual rate of litter-fall was 330 g/m² (Table 3). Leaves were 57% of the total, wood-fall was 27% and miscellaneous-fall was 16%. Leaf-fall exhibited a peak between October and November (Fig. 1). Daily rates did not exceed 1.3 g/m² even during peak leaf-fall. Fruit and wood-fall were relatively constant with the exception of respective peaks during February and April, 1971. Peak acorn-fall was in February, but quantities were small (no higher than 0.4 g/m²•day).

Ground litter exhibited a rapid build-up between December, 1970 and October, 1971; remained high throughout 1972, and had decreased by 1976. Wood litter was still high in 1976, while miscellaneous litter had declined. Between the first measurement of litter standing crop in 1971 and the last one in 1976, all litter compartments increased (Fig. 2). The difference, divided by the time interval, yielded an average rate of increase of 250 g/m²•yr

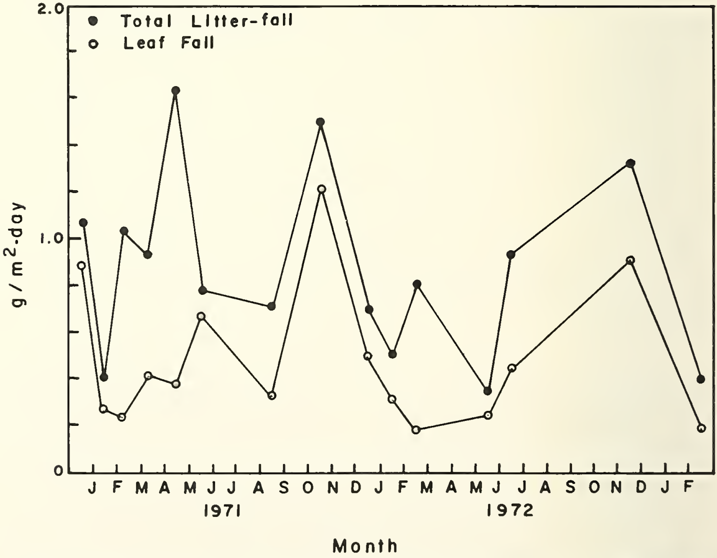

FIG. 1. Rates of litter-fall and leaf-fall in a sand pine forest located in the Ocala National Forest, Florida.

TABLE 3. Annual litter production (g/m^2) in a *Pinus clausa* forest located in the Ocala National Forest and a sandhill forest located in San Felasco Hammock, Florida.

	Leaves	Wood	Reproductive Parts	Miscellaneous	Totals
Sand Pine					
1971	205	86	--	58	349
1972	172	91	16	33	312
Mean	188	88	--	53*	330
Sandhill					
1977	217	28	--	33	278

*Includes acorns, seeds, and flowers.

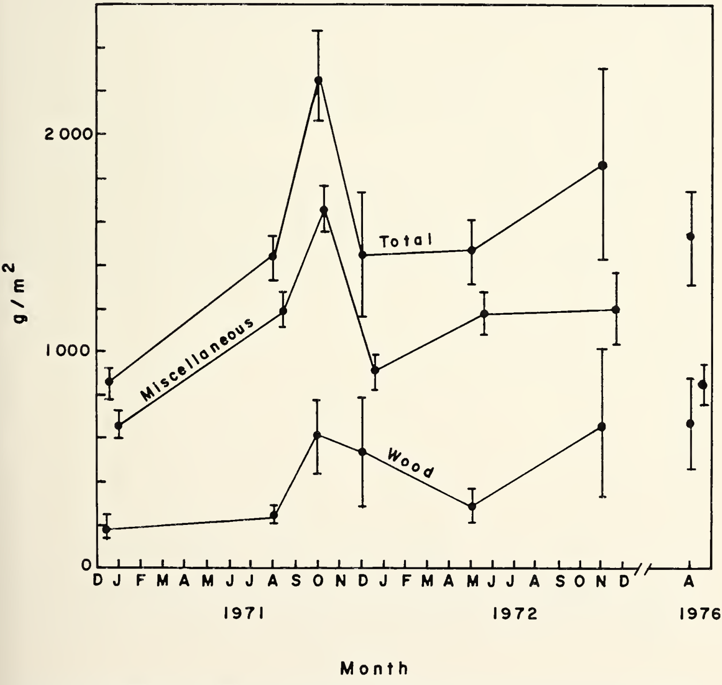

FIG. 2. Standing crop of litter and lichens in a sand pine forest located in the Ocala National Forest, Florida.

although it is obvious that most of the increase occurred in 1971. Peak standing crop occurred at the time of highest litter-fall. Ground lichen cover and biomass did not change significantly from its mean value of 107 g/m².

Sandhill Forest: The annual rate of litter-fall was 278 g/m² (Table 3). Leaves were 78% of the total, wood-fall was 10% and miscellaneous-fall was 12%. Peak of leaf-fall (Fig. 3) occurred during a 3-mo period for turkey oak and only for a short time for the long leaf pine. A second peak of leaf and litter-fall for turkey oak was observed in March.

Rates of total litter-fall during peak periods exceeded 3 g/m²•day but averaged 0.75 g/m²•day for the year and were less than 0.5 g/m²•day during most of the year. We found that baskets located on the forest floor yielded higher rates of litter-fall than did elevated baskets even when litter-fall rates were low. For example, during peak litter-fall, ground baskets collected approximately 4 times as much litter than elevated baskets. Only data from the elevated baskets were used in this study.

Standing crop of litter oscillated around a mean of 842 g/m² in the unburned control site (Fig. 4). We could not detect any net accumulation of ground litter. In the burned site, ground litter decreased to a mean of 484 g/m² or about half of the mean value in the control site. However, the amount of wood on the ground did not change significantly (103 g/m² after the burn vs 136 g/m² in the control site). After the fire, ground litter accumulated in the burned site and 29 mo after the fire it had almost reached the preburn value (Fig. 4).

DISCUSSION—The 2 forests exhibited similar rates of litter-fall but different patterns. The higher value measured in the sand pine forest is due mainly to differences in wood-fall and not significant. Leaf-fall was slightly higher in the sandhill forest. Turkey oak dominated leaf-fall in the sandhill forest. Peaks of litter-fall were of short duration and peak leaf-fall occurred

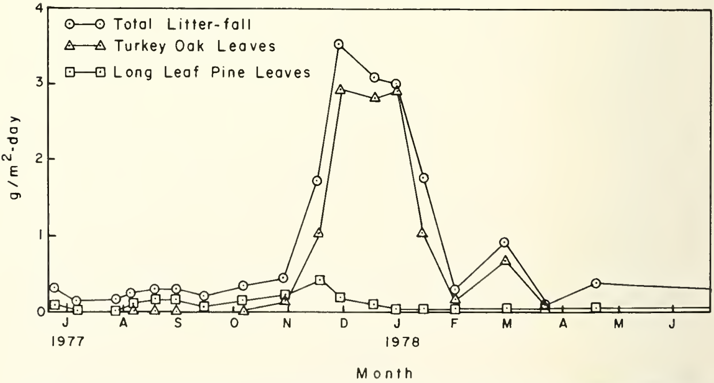

FIG. 3. Rates of litter-fall and leaf-fall in a sandhill forest located in San Felasco Hammock, Florida.

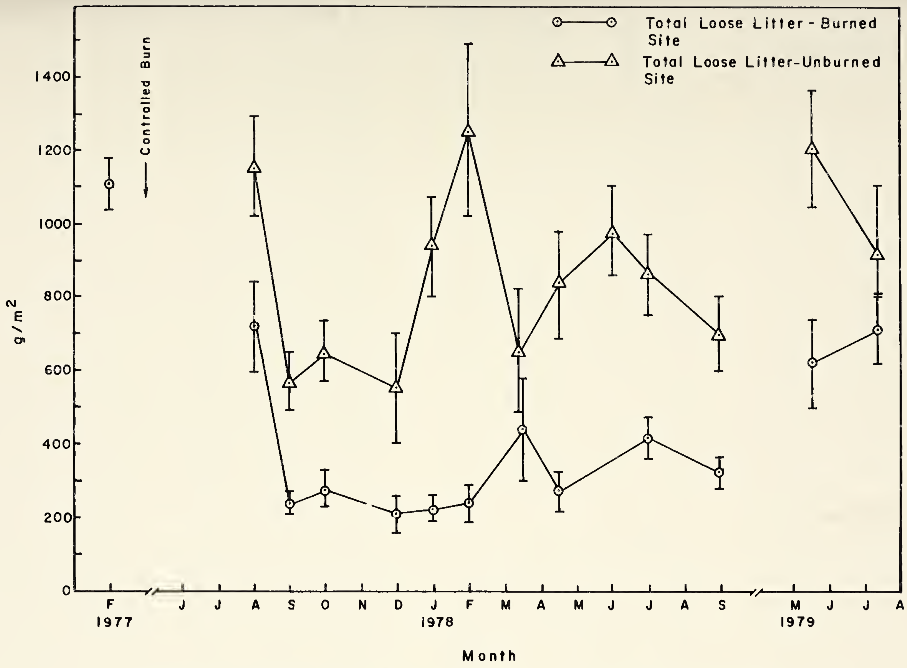

FIG. 4. Standing crop of litter in burned and unburned sandhill forests located in San Felasco Hammock, Florida.

earlier in the sand pine forest than in the sandhill forest. Peaks of wood-fall were measured in the sand pine forest but not in the sandhill forest.

Rates in the study forests are slow compared to other Florida ecosystems. For example, mixed hardwood forests growing adjacent to sand pine or sandhill forests exhibit rates of litter-fall of 1069 $g/m^2 \cdot yr$ or about 3 times higher than those of either of the study sites (Lugo et al., 1978). Litter-fall rates in mangroves and forested freshwater wetlands range between 510 and 1170 $g/m^2 \cdot yr$ (Brown and Lugo, 1982). However, highly-stressed scrub mangroves or scrub freshwater forested wetlands exhibit litter-fall rates in the range of 120-250 $g/m^2 \cdot yr$ (Brown and Lugo, 1982). These values are very close to those measured here for sandhill and sand pine forests. Thus, it appears that the lower rate of litter-fall in these forests is a function of extreme environmental stress rather than geographic position or climate.

The patterns of litter-fall may represent ecosystem response to environmental stressors. In the nearby mixed hardwood forests dominated by oaks, peaks of litter-fall occurred with the occurrence of frost and were similar to those observed in the sand pine forest although rates were many times higher (Lugo et al., 1978). Peaks of wood-fall were also observed in the mixed hardwoods and were attributed to the maturity of the forest and windy weather (Lugo et al., 1978). Soils in hardwood forests contain more organic matter and nutrients than those in sand pine and sandhill forests (Laessle, 1942). In mangroves, peak rates of litter-fall occurred during rainy periods (Pool et al., 1975), while in freshwater forested wetlands, the peaks occurred in response to lower temperatures or extreme drought (Brown, 1978).

The litter-fall pattern of sand pine forest appears to respond in a similar fashion to most other Florida ecosystems (to frost), but the lower rates reflect lower soil fertility. The sandhill forest maintains dead leaves on the tree through winter and the winter leaf-fall peak continues to exhibit higher rates of leaf-fall for a longer time period. A common winter site in Florida for example, are the turkey oaks with their crops of dead leaves still on trees. This strategy may have an advantage in retaining volatile nutrients during winter fires, retaining dead leaves in the forest during windy winter periods, or perhaps by allowing more time for the retranslocation of nutrients into the tree.

Litter standing crop was higher in the sand pine forest than in sandhill forest. The sand pine forest also accumulated litter between 1972 and 1976 while the sandhill forest did not. Adjacent mixed hardwood forests have a standing crop of 820 g/m^2 and exhibited little annual fluctuation (Lugo et al., 1978). The 2 study forests had higher litter standing crops and exhibited more annual variability (Figs. 1 and 4). The higher standing crops of litter in these 2 stressed forests is probably related to slow decomposition between fires.

The fire that occurred in the sandhill forest gave us the opportunity to measure the resulting loss in standing crop (about 50%) and the return of litter standing crop to its initial value. Historically, fires in sandhill forests occurred at a frequency of about 3-5 yr (Snedaker, 1963). Our observations suggest that there is enough time for the litter compartment to reach pre-burned standing crop conditions between fires occurring at these frequencies. Because fires occurred at a lower frequency in sand pine forests (on the order of 10-20 yr; Snedaker and Lugo, 1972) there is more time for litter accumulation and thus, the standing crop is higher. Without fires, litter would build up in these ecosystems as it has happened in Welaka, Florida (Veno, 1976), because the turnover of litter is low in both ecosystems (Table 4). For comparison, the adjacent mixed hardwood forest exhibits a litter turnover rate of 1.3 times/yr or 4 times faster than either sand pine or sandhill forest (Lugo et al., 1978).

TABLE 4. Turnover of litter compartments in 2 Florida ecosystems. For the sand pine forests we used the average standing crop value for the period when the compartment was in steady state.

	Standing crop g/m²	Input g/m²•yr	Turnover Rate Times/Year
Sand Pine Forest			
Wood	553	88	0.16
All litter	1593	330	0.21
Sandhill Forest			
Wood	135	27	0.20
All litter	842	278	0.33

The net accumulation of litter in the sand pine forest was of the same order of magnitude as total litter-fall (250 vis a vis 330 $g/m^2 \cdot yr$) and therefore, decomposition rate must be negligible. The low nutrient condition of these forests could be reflected in high C/N ratios and thus reduced microbial decomposition. Gamble (1971) found that lichens, shrubs, and the litter layer accumulated radioactive Cs 137 and that mycorrhizal associations were involved in nutrient retentions and translocation. These associations working in concert with the observed dense root-mats that are typical of the sand pine forest would assure that elements released by fire or brought to the surface by burrowing organisms (common in both forests and up to 64 borrows/m^2 in sand pine forests) are incorporated into the ecosystem and transported to photosynthetic leaves. Similar mechanisms of nutrient transfer in ecosystems with dense root mats in sandy soils have been documented in the Amazon (Herrera et al., 1981).

In summary, sandhill and sand pine forests exhibit similarities and differences in the dynamics of litter turnover. Because both are severely stressed ecosystems, both exhibit slow rates of litter-fall, they have large amounts of litter standing stocks, and in the absence of fire, both have slow litter turnover rates. However, these forests differ in the pattern of litter-fall. While sand pine forests exhibit patterns that suggest a normal response to the onset of winter, sandhill forests retain leaves on the tree longer, and spread out the period of higher leaf-fall. This may be a favorable strategy for retaining nutrients during frequent fires (3-5 yr intervals) and during periods of high wind associated with the winter months. Sand pine forests are denser and winds do not redistribute litter. They suffer catastrophic but low frequency fires (10-20 yr intervals). Both types of ecosystems exhibit other mechanisms for nutrient recycling that compliment fire and these include an abundance of burrowing organisms, mychorrizal relationships, and temporary nutrient storage in herbaceous layers and lichens.

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CURRENT STATUS OF MANAGING TOMATO DISEASES IN SOUTH FLORIDA BY BIOENVIRONMENTAL MEANS

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Abstract: *Current methods used to manage plant diseases in commercial tomato fields in Florida and their effectiveness in grower practice are compared. Host plant resistance, fertility management, the use of plastic mulch and staking of plants are bioenvironmental methods that have made significant contributions to management of specific tomato diseases.*

Tomatoes rank first among vegetable and fruits consumed in the U. S. A. (Rick, 1978). There are about 17,361 ha of tomatoes grown per year in Florida (Florida Crop and Livestock Reporting Service, 1981). Tomatoes returned a gross of $244,240,000 to Florida farmers in 1979-80, more than any other vegetable crop (Florida Crop and Livestock Reporting Service, 1981). Florida's commercial tomato crop is unique in that it is harvested from October to June, the off-season for most of the other tomato-growing areas of the U. S. A. Almost all of Florida's tomato crop is sold in the fresh-market trade. Diseases of tomatoes that reduce yield and fruit quality are frequently severe (Jones et al. 1969). Prior to the advent of synthetic organic fungicides in the 1940s the control of plant diseases was usually marginal with periodic heavy losses. Spectacular control has been achieved with fungicides for many diseases since the 1940s. However, as environmental problems and costs of pesticides increase, more emphasis is being placed on 'bioenvironmental' control or management methods. Bioenvironmental control is: "any nonchemical control method utilized to reduce pest populations by environmental manipulations and biological control". (President's Science Advisory Committee, 1965). Although bioenvironmental management methods have been used for many years in Florida, the contribution of these methods in the management of tomato diseases in Florida has not been focused upon.

We survey the types and the extent of use of bioenvironmental and pesticide management methods on tomato diseases in the field in Florida and their experienced effectiveness under commercial grower conditions.

Methods—Plant disease management practices used by tomato growers in south Florida were evaluated to determine how tomato diseases were currently managed. Post-harvest problems, viruses, nematodes, and physiological problems were not considered in this study. Table 1 shows the major fungal and bacterial diseases of tomatoes in Florida with categories of management methods used against them.

RESULTS—In Table 1, each category of management methods for each disease is given a rating consisting of a number indicating the extent of use and a letter indicating experienced effectiveness under commercial grower conditions. Each category of management methods may contain several different methods. The ratings are an estimate of the average use and average experienced effectiveness of methods within the categories. The ratings for extent of use are: 1 = major use, 2 = some use, 3 = little or no use. The ratings for experienced effectiveness are: A = excellent, B = moderately effective, C = some use, D = not effective, and E = detrimental. The number indicating use is an estimate of the current use of the method by growers in the sense of its current contribution to the control or management of that disease. For example, if a disease is already managed by host resistance, and fungicide sprays rated moderately effective against the disease are sprayed on the plant to manage a second disease, the use rating of fungicide sprays for the first disease would be a 3, indicating that fungicides are of little use in its management. For instance fungicides used to control early blight, caused by *Alternaria solani*, would also be effective against grey leaf spot, caused by *Stempylium solani*. However, all currently grown Florida commercial tomato cultivars have high resistance to grey leaf spot, thus fungicide sprays on grey leaf spot (Table 1) are rated 3 for use. There were some differences in ratings of experienced effectiveness for some of the management methods among the researchers. There is some difference in the extent of use of some methods in different areas of south Florida.

DISCUSSION—Some of the bioenvironmental methods used to manage tomato diseases in south Florida are highly effective and are usually the methods of choice for these diseases. Examples include host plant resistance for, the *Fusarium* wilts of tomato incited by *Fusarium oxysporum* Schlecht. f. sp. *lycopersici* (Sacc.) Snyder & Hans. race 1 and race 2, Verticillium wilt incited by *Verticillium albo-atrum* Reinke & Berthold, nailhead spot incited by *Alternaria tomato* (Cke) Weber, and grey leaf spot incited by *Stemphylium solani* Weber (Crill et al., 1977); liming and fertilizing of soil in the management of grey mold, *Botrytis cinerea* Pers ex. (Stall, 1963) and use of full-bed covering-plastic mulch and/or staking of plants for fruit rots incited by soil-borne fungi such as *Rhizoctonia solani* Kuhn., *Sclerotium rolfsii* Sacc., and *Pythium aphanidermatum* (Eds.) Fitzp.

The time of year a crop is in the field affects the intensity or severity of most diseases (Jones et al., 1969). There are some diseases (e.g., *Fusarium oxysporum* 'crown rot', *Phytophthora infestans* 'late blight', *Sclerotinia sclerotiorum* 'white mold') that are cool-weather diseases and others, (e.g., *Pseudomonas solanacearum* wilt and *Xanthomonas vesicatoria* leaf spot), that are warm weather diseases. Some diseases can be avoided if tomatoes are grown when the environment is least favorable for the particular disease. However, no matter what time of year tomatoes are planted in south Florida some diseases will develop. The time of planting of a tomato crop is usually

TABLE 1. Availability, use and experienced effectiveness of methods used to manage the major fungal and bacterial diseases of tomato in commercial fields in Florida.

Pathogen	Biological Control	Host Plant resistance	Chemical control	Cultural								
				Sanitation	Crop Rotation	Planting Date	Clean seed, Trsplts	Water Mgt.	Fertility Mgt.	Tillage	Staking	Plastic Mulch
FOLIAR DISEASES												
Phytophthora infestans	0	0	1-B	z	z	2-A	2-B	z	z	z	z	z
Xanthomonas vesicatoria	0	0	1-C	2-C	3-C	2-B	2-B	z	z	z	2-C	z
Stemphyllium solani	0	1-A	3-B	3-C	3-C	3-C	3-B	z	3-C	z	z	z
Alternaria tomato	0	1-A	3-B	3-C	3-C	3-B	3-B	3-C	3-C	z	z	z
Alternaria solani	0	2-C	1-B	3-C	3-C	2-B	2-B	3-B	2-B	z	z	z
Botrytis cinerea	0	0	3-B	3-C	3-C	2-B	3-B	z	1-A	z	z	z
Cladosporium fulvum	0	2-C	2-B	3-C	3-C	2-B	z	z	z	z	2-B	z
Corynespora cassicola	0	0	1-B	3-C	3-C	2-B	z	z	z	z	z	z
Phoma destructiva	0	0	1-A	3-C	3-D	3-C	3-B	z	z	z	z	z

TABLE 1. Continued.

Pathogen	Biological Control	Host Plant resistance	Chemical control	Cultural Sanitation	 Crop Rotation	 Planting Date	 Clean seed, Trsplts	 Water Mgt.	 Fertility Mgt.	 Tillage	 Staking	 Plastic Mulch
SOIL-BORNE DISEASES												
Fusarium oxysporum	0	1-A	3-A	3-C	3-C	2-D	3-C	3-C	3-B	z	z	z
F. oxysporum 'crown rot'	0	0	1-E	3-C	3-C	2-B	z	3-C	3-C	z	z	z
Verticillium albo-atrum	0	1-B	2-B	3-C	3-D	2-C	z	z	z	z	z	z
Pseudomonas solanacearum	0	3-C	1-B	3-C	3-C	2-B	3-C	3-B	z	z	z	z
'Damping-off'	0	0	2-B	3-D	3-C	2-B	z	3-B	z	z	z	z
Rhizoctonia[e] *solani*	0	0	1-B	3-C	3-C	2-C	z	3-B	z	z	1-A	1-A
Sclerotium rolfsii	0	0	1-C	3-B	3-D	2-B	z	3-B	3-C	3-C	2-A	1-A
Sclerotinia sclerotiorum	0	0	1-B	3-C	3-B	2-B	z	3-B	z	z	2-C	z
Phytophthora parasitica	0	0	z	3-C	3-C	2-C	z	3-B	z	z	2-B	2-B

a – 0 = none available.
b – z = not applicable or not known to be a factor.
c – Current use of control method; 1 = major use, 2 = some use, 3 = little or no use.
d – Effectiveness of control obtained with method; A = excellent, B = moderately effective, C = of some use, D = not effective, and E = detrimental.
e – Fruit rot.

determined by economic conditions. In a few cases, the presence of diseases or other pests are considered.

Many of the bioenvironmental management methods listed in Table 1 may not singly contribute greatly to the management of a particular disease, but they may contribute in some way to the management of several diseases. The total management of most diseases is the result of a combination of methods. Factors such as time of planting will also affect the effectiveness of some of the other disease management methods. In most cases we do not yet have enough information on the contribution of a particular bioenvironmental method to the management of a particular disease under a particular set of circumstances. More study is needed on various aspects of the interaction between management methods.

None of the tomato diseases in south Florida are managed presently by biological control in the sense of the use of one organism against another. However, natural biological control may be operating to some extent in most host-pathogen interactions.

Xanthomonas vesicatoria leaf spot, *Phytophthora infestans* late blight, and *Alternaria solani* early blight are managed primarily by fungicides. Excellent control of late blight and early blight and moderate control of bacterial spot can be achieved with fungicides. However, when environmental conditions are favorable for disease development, conditions are usually unfavorable for applying foliar fungicides. This accounts for our rating foliar fungicide treatments as moderately effective in commercial use.

Bioenvironmental methods have recently been developed for several diseases previously controlled primarily with pesticides. The effect of these bioenvironmental management measures on pesticide usage, however, was not determined. On the surface one would expect that pesticide usage would decline with the development of effective bioenvironmental measures. However, in many cases, fungicides effective on foliar fungal diseases now controlled by bioenvironmental means, are used to control diseases not yet controlled by bioenvironmental means. A thorough survey is required to determine whether reduction in fungicide usage on tomatoes has occurred with the development of bioenvironmental measures.

As tomato culture changes and exchange of plants, materials and people between areas increases, there will be changes in the composition of the disease complexes affecting tomato culture. Target spot and *Fusarium* crown rot were not observed in southeast Florida in 1960. In 1980 they were significant problems. As the mixture of important diseases changes, changes in the combinations of methods used to manage them will also be needed. Bioenvironmental methods (hopefully) will be the methods of choice, when available, for managing tomato diseases in the future. Because changes in disease complexes can be rapid and management methods using pesticides are usually more quickly developed, pesticides in the future may serve as interim management methods or for situations where no other feasible method is available.

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Earth Sciences

EARTHQUAKE HISTORY OF FLORIDA: 1727 TO 1981

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Abstract: *Published accounts of seismic events reported in Florida are reported from the time of occupation of the Florida Peninsula to December 1981. Events are cited by date, time and geographic locality. Note is taken that a continuously recording seismograph has been operational since October 1977.*

While the seismic events reported from the Florida peninsula and panhandle have indeed been rare, earthquakes have occurred and been felt. Thirty-three are identified herein. Spanning over 250 yr, reports have come from Pensacola to Key West. Shocks varied from slight shudders to violent shakings that destroyed buildings.

Few records of seismic shock have corroborative seismic evidence in the form of seismogram data. Many of the shocks reported or recorded in Florida seem to be related to seismic events elsewhere in North America.

Earliest seismic reports were plotted on the 10-point, Rossi-Forel Scale. This scale measured earthquake intensity and was based on a subjective set of criteria. The more recent Modified Mercalli Scale is a 12-point scale that is slightly more objective. Earthquake ratings on this scale are written as upper case Ms, followed by the Roman numeral designating the intensity of the tremor. For example, MMIV would represent an intensity 4 shock on the Modified Mercalli Scale. Rossi-Forel estimates have been converted to Modified Mercalli intensity equivalents in this paper.

12 October 1727. "Severe" tremors were reported and mentioned by Campbell (1943) and Lane (1976). However, the original record of these quakes has been lost. A severe shock was reported in New England on this date at 10:40. Reports of another shock came from Martinique on the same day. The relationship of either of these to the St. Augustine tremor was not established.

6 February 1780. A mild tremor was reported from Pensacola on this date (Lane, 1976). No damage was reported.

8 May 1781. A severe earthquake was reported at a military installation near Pensacola. While no fatalities were reported, shocks tore ammunition racks from barracks walls and leveled a house in the area (Lane, 1976).

7 May 1842. This tremor was felt from Florida to Louisiana. It may have been associated with a severe earthquake that struck Santo Domingo at about the same time. Sources report the disappearance of some Florida lakes on the day of this earthquake (Niles National Register, 1842).

8 February 1843. An earthquake was reported from the rural areas of the State. This tremor might have been associated with a tremor in the West Indies which occurred at the same time (Lane, 1976).

12 January 1879. Two severe shocks of about 30 sec each occurred from an area from Ft. Myers to Daytona and from Tallahassee to Jacksonville, and from all areas in between. The epicenter was located at 29°30'N, 82°00'W (U.S. Coast and Geodetic Survey, 1938). The shock was reported by hundreds of residents over a 25,000 square mile area of the Florida peninsula, and ranged from MMVIII to MMIX.

At St. Augustine, articles were thrown from shelves. In other locations, windows rattled violently and walls cracked. Rockwood (1880) indicated that the tremor progressed from the NW toward the SE between Gulf Hammock and Okahumpa. In the Tampa Bay area, Campbell (1943) states that the shock seemed to move from SW to NE and was preceded by a rumbling sound ". . . as of a distant railroad train." MMVI was reported near Gainesville (Lane, 1976).

22-23 January 1880. On this date, a violent series of earth tremors struck at Cristobal, Cuba. At about the same time, 5 shocks were felt in Key West. Additional, more gentle shocks were felt in Key West through 26 January (U.S. Coast and Geodetic Survey, 1938).

8 January 1886(a). Reid (1886) reported a shock in Jacksonville with no damage or injuries.

31 August 1886(b). There were a series of strong shocks in Charleston, South Carolina on this date. The tremors in Charleston began at 21:51. In Tampa, residents reported 2 shocks, the first at 21:51, the second at 22:00.

The first appeared to move NE to SW, while the second seemed to travel SW to NE.

In St. Augustine, church bells tolled as the tremor passed, while near Tallahassee, the water in Lake Jackson disappeared. A well near Graceville began to flow (Campbell, 1943).

1-9 September 1886(c). Many reports of shocks were from throughout the area, with most coming from Jacksonville. These tremors were probably associated with aftershocks from the Charleston, South Carolina earthquake (Reid, 1886).

22 September 1886(d). A 3-sec shock was felt in Archer, Florida. No damage, no injuries (Reid, 1886).

29 September 1886(e). Slight shock reported. No injuries, no damage (Reid, 1886).

22 October 1886(f). A single tremor passed through Jacksonville causing windows and dishes to rattle. On this date, similar shocks were felt in Charleston, South Carolina, as well as in Atlanta and Augusta, Georgia (Campbell, 1943).

20 June 1893. A shock of at least 10 sec duration was felt in Jacksonville, MMIV (Reid, 1907).

10 October 1900 (Stover et al., 1979). Reid (1907) estimates the epicenter of this tremor to have been at 30°20'N, 81°40'W. It was felt at Jacksonville at 11:15 and afterward. Eight distinct shocks were reported without damage and injuries. The intensity of this tremor was MMV. A tremor was also felt in Lake City about this time.

20-21 May 1902. Residents reported hearing a noise like heavy cannon fire at a distance. The noises preceded the actual tremor by about 3 min. Tremors were slight and without damage (Reid, 1907).

23 January 1903. A shock wave of MMVI was felt in north Florida and in Savannah, Georgia. No damage (Lane, 1976).

4 September 1905. MMIII shock was accompanied by slight rumbling noises. Duration was 10 sec without damage (Reid, 1907).

20 October 1924. A tremor of intensity MMIV shook the area. Windows and doors rattled, but there was no damage (U.S. Coast and Geodetic Survey, 1924). An earthquake was felt throughout Virginia, Tennessee and South Carolina at about the same time (Bollinger, 1977).

19 July 1930. Widespread shocks were felt over a wide area of west-central Florida. The shocks were so evenly spaced that blasting, at first, was thought to be the source of the shocks. However, Campbell (1943) points out that the size of charge necessary for a shock to be felt over such a large area would be highly unusual. Furthermore, no blasting of any sort was scheduled or recorded on that day. He suspects a seismic origin for the shocks.

13 November 1935. Two short tremors were felt. The second tremor lasted 15 sec. In Palatka, shocks were abrupt and forceful enough to cause people to run from their homes and into the streets. No damage or injuries were reported (Seismological Society Bulletin, 1936).

26 December 1940. A slight shock was felt in the Tampa Bay area. Campbell (1943) reports that a seismic origin for this shock is in doubt, but gives no other details. However, the U.S. Coast and Geodetic Survey (1940) does list a tremor on this date and time.

19 January 1942. Five to 7 evenly spaced tremors were felt from Miami throughout the Everglades. Each shock lasted about 1 min, and the shocks were spaced at 3 min intervals (Campbell, 1943). In Hollywood, whole houses shook. Moorehaven, on the south shore of Lake Okeechobee, reported 12 tremors. Still farther west, Alva reported 20 shocks, ranging from MMV to MMVII (U.S. Coast and Geodetic Survey, 1942).

22 December 1945. Press reports state that alarmed citizens felt a seismic shock in the area. A seismograph at Spring Hill College, near Mobile, Alabama recorded a slight earthquake on this date and time (U.S. Coast and Geodetic Survey, 1946).

8 November 1948. A sudden jar caused doors and windows to rattle. Residents report an accompanying sound like distant heavy explosion. Recorded as MMV (U.S. Coast and Geodetic Survey, 1948).

18 November 1952. This was a MMIV tremor felt in Lake City and in Quincy. A policeman in Quincy is said to have noted the exact time of the passing tremor on the back of a parking citation which he was issuing at the time (U.S. Coast and Geodetic Survey, 1952).

29 March 1953 (Stover et al., 1979). Slight tremor felt in Orlando.

2 March 1964. No surface expression of a tremor, but significant oscillations were noted in water well data collected by the United States Geological Survey. These oscillations were possibly associated with the Good Friday Alaska earthquake which happened on this date (Stencil, 1976).

27 October 1973(a). Slight tremor reported in a broad area of central Florida (Stover et al., 1979).

5 December 1973(b). Tremor reported at 11:30, Seminole and Orange counties.

4 December 1975. A MMIII to MMIV tremor was detected by most residents within a 10-mi radius of Daytona Beach (Stover et al., 1979).

27 November 1977. In October, 1977 the Earthquake Seismograph Station at the University of Florida became operational (Smith, 1978). No local events were recorded until November, 1977 when slight shock was recorded north over peninsular Florida. This tremor was not large enough to be felt, but was recorded as Richter magnitude .8.

At this writing (December, 1981) no additional tremors have been recorded. However, with the advent of continuous seismic recording for Florida, continuous updating of this record may now be accomplished. (Smith, Dec. 1981, pers. comm.)

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Biological Sciences

SHELL SHAPE AND BURROWING HABITS OF MARINE PELECYPODS

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Abstract: *The ratio of convexity of the valves to the length of the valves is a factor in the burrowing habits of marine pelecypods. The pelecypods with a high percentage of convexity, 55% or greater, tend to be slow burrowers. Exceptions to this rule are the Cardiidae and* Neotrigonia. *Those that have a low percentage of convexity, less than 40%, tend to be rapid burrowers. Deposit-feeding groups of pelecypods commonly have a low percentage of convexity, are of small to medium size, and are rapid burrowers. Pelecypods that have a high percentage of convexity and spirally-enrolled prosogyrate beaks, as in* Glossus, *are sluggish, shallow-burrowing suspension feeders.*

The ratio of the convexity of the valves to the length of the valves of burrowing marine pelecypods was recorded for more than 1,300 specimens. Convexity is the measurement through the valves, and some malacologists use such terms as diameter, thickness, breadth, width, or even section for this measurement. I believe that the length, the anterior-posterior distance of the valves, is a more significant measurement than height when one is considering the shape of the valves in relation to burrowing and feeding habits. Nearly half of the data used in this study were obtained by measuring specimens in the mollusc collection at the Florida State Museum; the remainder were taken mainly from regional faunal monographs. Samples of less than 5 specimens were not included (See table 1). Nestlers and borers were not considered, nor were epifaunal species. The sources of data at my disposal precluded any attempt at a detailed analysis of most major groups such as the veneraceans, tellinaceans, cardiids, and lucinids. In a diagram Kaufman (1969) noted that convexity of the valves was related to speed and depth of burrowing. Stanley's (1970) observations on some species of burrowing pelecypods were the main source on the habits of burrowing pelecypods.

As Stanley (1970) pointed out, almost without exception the deposit-feeding species of pelecypods he observed are rapid or moderately rapid burrowers. Unlike suspension feeders, they must be able to move around on the bottom to forage for food. Stanley also notes that deposit feeders generally have thin, smooth, and streamlined shells. I have noted (Nicol, 1964, 1978) that the Protobranchia and Solemyidae, all of which are deposit feeders, are small to medium in size. These pelecypods rarely attain a size of more than 100 mm. The nuculids are commonly the smallest of the protobranchs, rarely attaining 40 mm in length. The Nuculidae are the most convex (52%) of the deposit-feeding taxa (Table 1); the remainder have a mean convexity of less than 40%. The commonly small size of the shells of nuculids may give them an advantage in moving through sediments more easily than the larger nuculanids, malletiids, and deposit-feeding tellinaceans. The protobranchs, incidentally, were nearly as large in the Ordovician as they are today. The deposit-feeding tellinaceans, also, do not attain a large size (Nicol, 1964, 1978). Maximum size of these tellinaceans is about 115 mm. Many species of suspension-feeding pelecypods attain a size of more than twice that of the largest deposit feeders. Does deposit feeding limit the maximum size of these animals? In the pelecypods, at least, it appears so.

The most convex pelecypod, with the exception of a few species of cardiids, is the genus *Glossus*, with a convexity to length ratio of almost 100%. The shell is thin and light, and the prosogyrate beaks are spirally enrolled. Owen (1953) states that *Glossus* is found on soft muddy bottoms, is a very slow and shallow burrower, and is a suspension feeder. The highly convex form coupled with prosogyrate beaks apparently evolved in several families of suspension-feeding pelecypods (*Treatise on Invertebrate Paleontology*, 1969). As an example, the genus *Isoarca* has a general shell form similar to *Glossus* (Nicol, 1947). This Jurassic and Cretaceous pelecypod had taxodont teeth and was probably like *Glossus*—a slow, shallow-burrowing suspension feeder. *Isoarca* was most probably an aberrant offshoot from an arcacean or mytilacean ancestor. Other families that have some or all genera with these characteristics include the Dicerocardiidae, Lucinidae, Ceratomyopsidae,

TABLE 1. Taxa of marine pelecypods with the mean percentage of convexity, the range of the percentages of convexity and the sample size. The asterisk (*) indicates that the groups' burrowing habits have been observed.

Taxa	Mean %	Range %	Sample Size
1. *Glossus**	91%	73%-100%	25
2. Cardiidae*	79%	41%-222%	94
3. *Meiocardia*	76%	63%- 79%	5
4. Noetiidae*	76%	67%- 83%	10
5. Anadarinae*	75%	44%- 89%	44
6. *Cucullaea*	71%	64%- 75%	14
7. Ungulinidae*	67%	47%- 89%	16
8. *Anodontia**	66%	58%- 76%	5
9. *Neotrigonia**	62%	52%- 70%	7
10. Carditidae*	60%	37%- 75%	28
11. Veneridae*	60%	25%- 96%	294
12. *Fimbria*	58%	45%- 68%	16
13. Glycymerididae*	58%	31%- 76%	43
14. Divaricellinae*	57%	50%- 67%	6
15. Thyasiridae*	55%	36%- 75%	5
16. Corbulidae*	55%	40%- 80%	21
17. Lucinidae*	54%	31%- 93%	27
18. Nuculidae*	52%	21%- 67%	26
19. *Arctica*	51%	46%- 61%	37
20. Limopsidae*	49%	31%- 64%	17
21. Verticordiidae	49%	33%- 68%	7
22. *Astarte**	48%	38%- 68%	11
23. Mactrinae*	44%	14%- 70%	59
24. Crassatellidae	44%	32%- 56%	21
25. Myidae*	42%	35%- 50%	6
26. Donacidae*	41%	15%- 65%	49
27. Poromyidae	41%	27%- 71%	7
28. Thraciidae	40%	32%- 58%	21
29. Mesodesmatidae*	39%	22%- 61%	15
30. Semelidae*	38%	13%- 78%	49
31. Cuspidariidae	37%	20%- 75%	28
32. Periplomatidae	35%	30%- 40%	6
33. Laternulidae	35%	31%- 40%	8
34. Lutrariinae	33%	17%- 50%	9
35. Nuculanidae*	31%	8%- 59%	63
36. Tellinidae*	31%	14%- 63%	187
37. Psammobiidae	30%	17%- 51%	42
38. Solecurtidae	25%	18%- 32%	12
39. Malletiidae	24%	12%- 47%	20
40. Cultellidae	14%	7%- 21%	10
41. Solenidae*	13%	8%- 18%	14

Megalodontidae, Pholadomyidae and Cardiliidae. Even one genus, *Pecchiolia* of the Verticordiidae (Septibranchia), has assumed the *Glossus*-like shape. This form of the pelecypod shell is not common in the Paleozoic, although 1 Silurian genus assumes a *Glossus*-like shape. Three Devonian genera, 1 Mississippian and 1 Pennsylvanian genus have this shape, and at least 3 Permian genera superficially resemble *Glossus*. This shell shape becomes more common in the late Triassic with at least 7 genera showing it, but the peak of diversity occurred in the Jurassic with at least 12 genera that look like *Glossus*. In the Cretaceous 7 genera and in the Tertiary 6 genera assume this shell shape. Recent faunas have 2 well known examples, *Glossus* and *Meiocardia*, and both of these genera are relicts. It seems reasonable to presume that most of these genera, with the exception of *Pecchiolia*, were or are slow, shallow burrowers and suspension feeders.

The Cardiidae have the second highest mean convexity of the 41 taxa listed in Table 1, and the range of convexity is greater than in any other taxon studied. Of the 94 specimens measured, only 3 had a convexity of less than 50%. In general, the cardiids are highly convex. Stanley (1970) observed the burrowing habits of 7 species of cardiids and found that cardiids are generally rapid to moderately rapid burrowers because of their large and muscular foot, but, because the siphons are short, the cardiids are shallow burrowers. The most remarkable genus of cardiids is *Corculum*, which has a shell that is greatly compressed in the anterior-posterior axis. Because of this extreme compression, the convexity is commonly 200%. This strange shape is probably an adaptation for allowing light to strike the symbiotic algae in the tissues of these cardiids (Rosewater, 1965). Species of *Corculum* are commonly found in shallow water in sandy places and associated with reef corals.

The arcaceans—Noetiidae, Anadarinae, and *Cucullaea* (Table 1)—all have a high percentage of convexity, and these are likely all slow and shallow burrowers. Stanley's few observations bear this out. Only 1 of the 16 ungulinid specimens measured had a convexity of less than 50%. These convex clams are probably all very slow burrowers, but few observations have been made on species of this family. *Anodontia*, like most lucinids, is a sluggish burrower.

Despite its high percentage of convexity, the genus *Neotrigonia* is a moderately rapid shallow burrower, but it has a large muscular foot. Stanley (1977) has compared the trigoniids with the cardiids as to burrowing habits. The carditids are slow and shallow burrowers according to Stanley (1970). The large family Veneridae has a wide range of burrowing habits from extremely rapid to slow burrowing. A detailed analysis of the living species of venerids should be made. As would be expected, there is a wide range in convexity in this family, but most venerids have a convexity of 50% or more. *Fimbria* is most likely a slow burrower because of its thick shell and high percentage of convexity, but no observations on its burrowing habits have been made. As in other burrowing arcoids, the Glycymerididae are slow shallow burrowers. A few species of glycymeridids have opisthogyrate beaks, as, for example, *Glycymeris (Glycymerella) decussata* (Linné). This species also has a different type of radial sculpture on the posterior side of the shell, which may be a factor in gripping the sediments. The relatively high convexity of most glycymeridids would suggest that these pelecypods are poor burrowers.

The Divaricellinae are slow burrowers but burrow more rapidly than most lucinids, and the divaricate sculpture aids in burrowing, according to Stanley. Kauffman (1969) claims that the Thyasiridae are rapid burrowers, which is unlike other lucinaceans. The Lucinidae are all slow to sluggish burrowers, according to Stanley. The Corbulidae appear to be very sluggish and shallow burrowers and probably prefer fine-grained sediments. *Arctica islandica* (Linné) is probably a moderately rapid burrower at best because of its relatively convex shell.

Oliver (1981) states that the Limopsidae are generally very poor burrowers. Even in a small sample (17 specimens measured, Table 1), the Limopsidae show a wide range of convexity, and Oliver (1981, Fig. 4, p. 64) illustrates the range of convexity in the Limopsidae. The limopsids appear to be grouped into those species that are elongate and have a low percentage of convexity (31%-45%) and those that are more rounded and convex, from 50% to about 65%. The 2 species of *Astarte* observed by Stanley (1970) were slow burrowers. The mactrids are mainly rapid burrowers, but thick-shelled species appear to be slow burrowers. Because of the thick shell, the crassatellids are probably slow burrowers. *Mya* is a slow burrower, according to Stanley. The donacids are rapid burrowers as are almost all tellinaceans.

Although the septibranchs (Verticordiidae, Poromyidae, Cuspidariidae) tend to have a low percentage of convexity, nothing is known concerning the burrowing habits of this deep-water group. One might infer from their specialized feeding habit that they are slow burrowers. In general, those taxa that have a mean convexity of less than 40% are probably rapid burrowers, and certainly species of the Solenidae, Cultellidae, Malletiidae, and Solecurtidae would be expected to be rapid burrowers.

Factors other than percentage of convexity do enter in to the burrowing rate of these infaunal pelecypods, such as the size and strength of the foot and length of the siphons. However, those pelecypods that have a high percentage of convexity, 55% or more, tend to be slow burrowers, and those pelecypods that have a convexity of less than 40% tend to be rapid burrowers. Of the 41 pelecypod taxa listed in Table 1, only 25 have been observed burrowing, and some of these are limited to observations on a single species within a taxon. More observations are greatly needed because the burrowing habits in many groups of pelecypods is as yet unknown.

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INDUCTION OF ABERRANT RAY NUMBERS IN *ECHINASTER* SP. (ECHINODERMATA: ASTEROIDEA) BY HIGH SALINITY—*Stephen A. Watts, Robert E. Scheibling*[1], *Adam G. Marsh and James B. McClintock*, Department of Biology, University of South Florida, Tampa, Florida 33620

Abstract: *Eggs of* Echinaster *sp. (Type II) were fertilized at field temperature and salinity levels of 25°C and 32‰. Embryos were transferred to 20, 25, 30°C and 25, 32, 39‰ S 2 da after fertilization. At 39‰, at all temperatures, approximately 45% of all metamorphosed individuals exhibited ray number abnormalities, with 4-ray individuals predominating over 3-ray individuals by a ratio of 2:1. Metamorphosed individuals at 25 and 32‰ S had the normal 5 rays. These data indicate that salinity can influence ray formation during early development.*

Classically, ray aberrancies in echinoderms have been attributed to genetic error and represent normal variation in ray numbers. Abnormal ray numbers have been attributed to injury, regeneration errors, nutrition, and congenital variation (for review see Hotchkiss, 1979; Moore, 1974). Hotchkiss (1979) stated that most ray abnormalities appeared to result from regeneration. There is little evidence for variation in arm number at metamorphosis (Hotchkiss, 1979).

The asteroid *Echinaster* sp. is a common inhabitant of the Gulf of Mexico and normally has 5 rays. In the field the frequency of abnormal ray numbers (4 and 6 rays) is 1:300 (Watts, pers. obser.). Verrill (1909) reported the frequency of abnormal 4-rayed *Asterias forbesi* as 1:3000. He suggested that ray aberrancies arise during early development. We report the induction of 3-and 4-rayed juveniles of *Echinaster* sp. by salinity.

Materials and Methods—Adult *Echinaster* sp. (Type II, Atwood, 1973) were collected in May, 1981 from the coastal waters of the eastern Gulf of Mexico, near Anna Maria Island, Florida. Spawning was induced in the laboratory with 0.001 M 1-methyladenine in seawater either *in vivo* via intracoelomic injection, or *in vitro* using excised ovaries and testes. Eggs and sperm were collected; the eggs were fertilized at field temperature and salinity (25°C, 32‰ S). The lecithotrophic embryos were maintained at field temperature and salinity for 2 da during which they developed into motile modified brachiolarian larvae as described by Atwood (1973). The larvae were then subjected to temperature and salinity combinations in a 3 x 3 factorial design (20, 25, 30°C; 25, 32, 39‰ S). Ranges of temperature and salinity experienced by *Echinaster* sp. in the field are 10-33°C and 25-35‰ S. Duplicate sets of 20 larvae were placed in 6 cm dia glass bowls containing approximately 25 ml of filtered (0.45 um millipore filter) seawater at each temperature and salinity combination. Treatment salinities were obtained by adding sea-salt (Marinemix, Marine Enterprises) or distilled water to seawater. Temperatures and salinities were controlled in constant environment chambers within 0.5°C and 1‰ S of selected values. Seawater pH remained constant in all T/S combinations (pH 7.6 ± 0.2). Animals were reared in the dark and water was changed daily. Treatment bowls were placed on rotators to insure adequate mixing. Juveniles ray numbers were recorded after 2 wk.

---

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RESULTS—The frequency of ray number anomalies in juveniles of *Echinaster* sp. are in Fig. 1. Approximately 45% of all individuals at high salinities (39‰), at all temperatures, had 3 and 4 rays instead of the usual 5 rays. Four-rayed individuals predominated over 3-rayed individuals by a ratio of 2:1. Less than 1% of the remaining larvae which developed at 25 and 32‰ S had abnormal ray numbers.

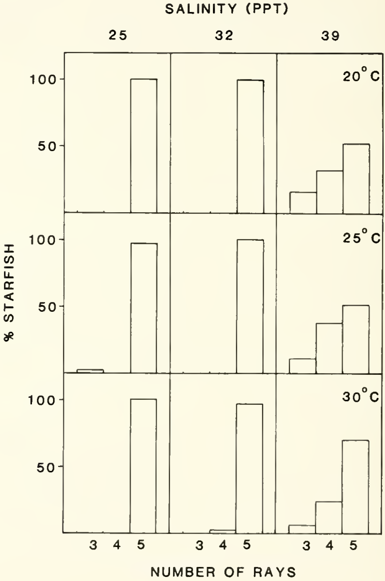

FIG. 1: Percentages of 3-, 4-, and 5-ray individuals of *Echinaster* sp. which developed at various temperature and salinity combinations. N = 40 for each combination.

DISCUSSION—The increased frequency of 3- and 4-rayed individuals of *Echinaster* sp. observed in this study is the first demonstration of a physical factor influencing ray number in asteroids. Verrill (1909) suggested that ray aberrancies arise during early development. Hotchkiss (1979) and Hotchkiss and Seegers (1978) suggested that suppression of the hydrocoel pouch on the ventral or dorsal horn of the hycrocoel during metamorphosis is the mechanism by which individuals become tetramerous. These results suggest that high salinities may induce ray anomalies in larval development. It is possible that concentrations of certain ion(s) may influence early development and cause ray anomalies. It is doubtful that salinity would affect ray numbers once the organisms become juveniles.

Hinegardner (1975) indicated the appearance of 4-part symmetry in several laboratory inbred lines of the sea urchin *Lytechinus pictus*. Between 1 and 10% of the progeny were found to be "square". He also found 2-, 3-, 4-, and 6-part symmetries in the urchins. He attributed the loss of 5-part symmetry in these individuals to undetermined genetic factors.

Moore (1974) described a number of test abnormalities in several regular echinoids. He indicated that some were the result of mechanical injury, but stressed the hypothesis that most resulted from metabolic upset. Moore et al. (1963) reported that an unusual increase in test abnormalities in the echinoid *Lytechinus variegatus* may have been caused by unusually low winter temperatures. Temperature changes did not influence ray anomalies in this study, although temperature extremes were not examined.

Harvey (1940) found that hyperosmotic solutions induced twins, triplets, and quadruplets in zygotes of the echinoid *Arbacia punctulata*. Marcus (1979) suggested that periproct plate deletions in adult *A. punctulata*, resulting from embryonic twinning using hypersaline solutions, may be due to unequal distribution of skeletal-forming material in the first 2 blastomeres, unequal blastomeres at first cleavage, or improper orientation of the larval skeleton caused by relationships intrinsic to twinned blastulae. It is possible that these aberrations are not the direct result of twinning, but may be the result, at least in some cases, of exposure of the embryos to hypersaline solutions.

ACKNOWLEDGMENTS—We thank Dr. J. M. Lawrence for discussions on the manuscript.

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Academy Symposium

FUTURE OF THE INDIAN RIVER SYSTEM

FOREWORD

THE INDIAN RIVER LAGOON SYSTEM, on Florida's Atlantic coast, is an important natural resource for both tourists drawn to the area and residents living along its shores. Sport and commercial fisheries in the Indian River system support a substantial fraction of the economy of the region. Boating and other recreational uses of these waters bring tourist dollars both directly and indirectly. It is important, therefore, that the ecology of the Indian River system be understood thoroughly and that the area be managed properly.

Interest in estuarine systems in general has developed relatively recently within the broader context of oceanographic research. Increased activity has been prompted in large part by greater population pressures in the coastal zone. At present, over one-third of the population of the United States lives in the coastal zone, and many more vacation or visit there regularly. Florida is especially prone to a concentration of people in its coastal zone, due to the moderating effect water has upon climate.

An increased motivation to understand and manage estuarine systems for a diverse variety of users has stimulated a series of meetings and resulted in an active participation by the scientific community and by management level personnel in industry and regulatory agencies. These meetings are, by design and of necessity, interdisciplinary to cover the broad scope of estuarine related problems and questions. Thus, such meetings have provided an opportunity for the free exchange of ideas across boundaries separating traditional disciplines.

The FIRST Symposium was one such meeting, sponsored by a consortium of organizations interested in the maintenance and wise use of the Indian River system. Approximately 200 participants gathered on the Florida Institute of Technology campus in Melbourne on 20 November 1981. A total of 25 oral presentations and 10 poster papers was presented, describing recent or ongoing research work in the Indian River, Banana River, Mosquito

Lagoon and adjacent fresh and coastal waters. This was the first time this limited geographical area has been singled out as the subject of a scientific meeting.

The proceedings of this symposium represent the many thoughts brought out at the meeting and makes them available in a concentrated and useful form to scientists and managers alike. The papers have been compiled to present first those describing the physical processes influencing lagoonal waters. These may be thought of as the causes of many biological and chemical characteristics revealed in other studies. The contributions dealing generally with the chemistry, biology and general ecology of the lagoons follow. Taken individually, these reports provide specific information over a broad range of topics. Collectively, however, they serve as a summary of our present understanding of the Indian River system. Gaps are apparent, but they point the way to future investigations.

An important result of the symposium was the realization that the Indian River system has not been studied as an ecological entity. Rather, a piecemeal approach has been taken, with investigators focusing on relatively narrow questions. Larger, more complex questions which remain unanswered include:

(1) What effects will increased population pressures have on the ecology of these waters, especially on the fisheries and the seagrass beds that constitute the foundation of the food web?

(2) What is the capacity of the Indian River system to absorb ecological assault, especially increased nutrient and toxic chemical concentrations, in view of its natural flushing ability?

(3) What are the relationship and relative importance of individual components of the food web existing in the Indian River lagoon system?

Such questions can only be answered by long-term, multi-disciplinary basic and applied research. A farsighted funding philosophy by state and federal agencies is required. This can lead to an optimum utilization of this irreplaceable natural resource, while maintaining its ecological integrity for future generations.

The success of the symposium and its proceedings is a result of a substantial effort by many individuals and assistance from several sources. The institutions supporting the FIRST organization include Florida Institute of Technology, Harbor Branch Foundation, University of Central Florida and Florida Sea Grant Program. Administrators at these institutions were understanding of the time commitments required of individuals who took part in the many organizational meetings. The Organization Committee consisted of John Trefry, Forrest Dierberg, Diane Barile and Maylo Murday at Florida Institute of Technology; John Montgomery and Ned Smith at Harbor Branch Foundation; Franklin Snelson, Lew Ehrhart and David Vickers at the University of Central Florida; and Leigh Taylor Johnson with the Florida Sea Grant Advisory Program in Brevard County. The symposium was dedicated to the memory of Cherie Down, who worked actively in the Indian River system while with the Brevard County Health Department. Finally, we would like to recognize the time and effort spent by Dr. Harvey A. Miller, Executive Secretary of the Florida Academy of Sciences, and Dr. Walter K. Taylor, Editor, in guiding the Associate Editors of this volume as the Proceedings of the Symposium took shape. We hope that the proceedings will be a useful reference, a summary of the status of contemporary knowledge, and a basis for comparison as man's influence further impinges upon this ecosystem.

John R. Montgomery
Ned P. Smith
Associate Editors

Link Port, Florida
October 18, 1982

PERSPECTIVES ON THE FUTURE OF THE INDIAN RIVER SYSTEM

Leigh Taylor Johnson

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Abstract: *The Indian River system extends from Ponce de Leon Inlet to St. Lucie Inlet and drains an increasingly populated watershed. The Future of the Indian River system Steering Committee was formed in April 1981 by representatives of 4 Florida scientific institutions to promote the wise utilization and optimum productivity of the Indian River system. This system is a significant economic, scientific, educational, recreational, and aesthetic resource. The FIRST Steering Committee will form a permanent organization to act as a clearing house for information on the Indian River system and to sponsor annual symposia. Symposia will alternate between research needs, and potential solutions will be discussed and referred to decision makers. The Indian River System Information Symposium is the first of the research meetings.*

The Indian River system extends from Ponce de Leon Inlet to St. Lucie Inlet. Included in the system are the Mosquito Lagoon, the Banana River, the Indian River, their tributary streams, and the inlets connecting the system to the Atlantic Ocean. In April 1981 the Future of the Indian River System (FIRST) Steering Committee was formed by representatives of Florida Sea Grant College, Florida Institute of Technology, University of Central Florida, and Harbor Branch Foundation.

The primary goal of FIRST is to promote the wise utilization and optimum productivity of the Indian River system. The general purposes are: (1) to promote an understanding of the processes occurring in and impacting on the system; (2) to encourage maintenance of the natural system as a continuing economic, scientific, educational, recreational and aesthetic resource; (3) to serve as a vehicle for communication and cooperation among interested research, government, industry, education, and citizen groups; (4) to provide a balanced forum for periodic discussion on the ecology and economy of the system; and (5) to generate support for these purposes.

Why were these goals considered necessary and important? First, the Indian River system supports a significant component of the economy of east-central Florida. Second, it provides a natural laboratory for both applied and basic research, as well as a fascinating classroom for natural history studies. Third, excellent recreational opportunities are available in water sports, and finally, the quiet beauty of the waterways and wetlands offers aesthetic rewards to both residents and visitors.

There are relatively few in-depth economic data on the value of water-related and water-dependent industries of the Indian River system. However, indicators are available. Volusia, Brevard, Indian River, St. Lucie, and Martin counties have an estimated 46 seafood dealers (pers. obs.

and comm. with local Marine Advisory Program Agents) handling Indian River system products, such as the blue crab, oyster, hard clam, spotted sea trout, black mullet, silver mullet, and red drum. Landings for the 7 mentioned fisheries totalled 1.8 million kg worth $1.2 million in 1979 for the 5 county area (NMFS, 1981). These are dockside values, or what the fishermen received. Processing activities, such as filleting and smoking fish, extracting roe from mullet or dressing them as billfish bait, shucking oysters and clams, and cooking and extracting the meat of blue crabs, employ many more people. Processing increases the value and variety of seafood products and heightens consumer interest.

The Indian River system is home to 57% of the local commercial and sport species of finfish during at least a portion of their life cycles (Gilmore et al., 1981). Thus, part of the offshore fishery is also dependent on the Indian River system.

Marinas, marine supply dealers, boat builders and repair facilities, fishing gear manufacturers, and bait and tackle dealers serve boaters, commercial fishermen, and sport fishermen. In Brevard County there are 172 establishments serving local and transient boaters and fishermen (pers. obs.). The 5 county area had 2,500 registered commercial boats and 42,000 registered pleasure boats in 1979-80 (Fla. DNR, 1981). A Melbourne marina estimates 40% of its boat storage space serves Orange County boats.

Tourists and new residents are attracted to east-central Florida by the many attributes of the Indian River system. Visitors from inland Florida, from other states, and from foreign countries contribute to the economy of the region while they are here. Many return to establish homes and become participants in the problems and benefits of the Indian River system.

Continued economic and other benefits provided by the Indian River system are dependent on a healthy lagoon ecosystem. Population in the 5 county area has grown from 318,200 in 1960 to a projected 774,300 in 1982 and to a projected 1,067,800 by 2000 (Univ. of Fla., 1980). This growth has included adaptation of the watershed and basin for human use. Clearing land and alteration of shorelines have affected drainage patterns. Opening inlets has allowed access of the oyster drill to lagoon waters, and dredging and construction of causeways and spoil islands have altered circulation of water in the estuary. Pesticides, fertilizers, thermal effluent from power plants, and industrial chemicals have all found their way into the Indian River system. Habitat changes and fishing pressure have affected plant and animal populations of the estuary. Long term residents can testify to a drop in abundance of many lagoon species, and a change in the appearance of the water in some sections (pers. comm. with Brevard County Marine Advisory Committee).

Environmentally-stressed areas of the Indian River system challenge scientists, governments, developers, and residents. Less disturbed parts of the waterway provide a basis of comparison for scientists seeking to understand the natural ecosystems of the region and how they have been influenced by human activities. The many papers and posters presented at the Indian River System Information Symposium are evidence of the tremendous value of the area as a scientific resource.

The FIRST Steering Committee has identified a need for a comprehensive approach to ensuring a healthy future for the estuary. They have proposed a set of objectives for reaching the goal of promoting the wise utilization and optimum productivity of the Indian River system. The first objective is an assessment of the condition of the system, the patterns of use and impacts, and the balance of economics and ecology. This would include identification of existing data, human resources, and facilities and equipment available. The Indian River System Information Symposium is an initial step toward meeting this objective.

A more difficult and perhaps more important objective of FIRST is to provide a forum for discussion of the future of the Indian River system. The FIRST Steering Committee proposes to expand and organize a meeting at which representatives from government, industry, research, education, and citizens' groups would meet to discuss a set of problems of the Indian River system. They would work toward agreement on how these problems should be approached, and identify research, management, and education priorities. This would provide elected officials, funding agencies, and other decision makers with a consensus for action from the many groups dependent on and interested in the future of the Indian River system.

The Steering Committee has proposed as its final objective the formation of a permanent FIRST Organization. This group could hold annual meetings alternating between research symposia and forums on research and management priorities. The Indian River System Information Symposium is the first of these research meetings. A permanent FIRST could also maintain lists of resource people and facilities, set up a central catalogue of data on the Indian River system, and keep open the lines of communication among industry, government, research, education, and citizens' groups.

ACKNOWLEDGMENTS—I thank the 4 sponsoring institutions for their support, advice and encouragement; J. Lowell Loadholtz, Brevard County Extension Service Director for his guidance and support in working with the marine community of the Indian River system; Eileen Salamone for her assistance in preparing this manuscript; and the members of the FIRST Steering Committee for their diligence and spirit of cooperation.

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Florida Sci. 46(3/4):132-134. 1983.

TEMPORAL DYNAMICS OF COPPER CHEMISTRY IN THE SHOAL GRASS, *HALODULE WRIGHTII* ASCHERS

(1) Thomas D. French and (2) John R. Montgomery

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Abstract: *Shoal grass,* Halodule wrightii *Aschers, is the dominant species of submerged marine vascular hydrophyte in the Indian River Estuary, Florida. Dissolved oxygen, temperature, salinity, pH, and redox potential or Eh measured over time gave evidence that shoal grass has resiliency and stability in the face of a major storm. Copper uptake by* Halodule *leaves was measured, and translocation of Cu through the plant to roots occurred. Monitoring of Cu in nearshore seagrass communities will directly reflect any abnormal amounts of metal into these systems.*

Seagrass ecosystems have been studied in detail over the past decade by the Seagrass Ecosystem Workshop sponsored by the International Decade of Ocean Exploration (McRoy and Helfferich, 1977). The need for evaluation and understanding of components of these systems, including heavy or trace metal cycling and distribution, was emphasized by Thayer et al. (1975), Burrell and Schubel (1977), and Ragsdale and Thorhaug (1980). Metals can move up the food chain to produce chronic and acute ailments in higher organisms (Forstner and Wittman, 1979), and thus research on metal uptake in seagrasses and other primary producers has broad implications. Our study focused on communities of the shoal grass, *Halodule wrightii* Aschers, because it is the dominant species in the Indian River, Florida (Thompson and Wolcott, 1976). We sought to determine copper content and distribution in various plant parts of *Halodule* and associated waters and the plants' role in the budget of an abnormal amount of copper introduced to the *Halodule* community by a major natural perturbation, in this case Hurricane David, September 1979.

Submerged marine vascular hydrophyte (Sculthorpe, 1967) communities are important to estuaries and other systems because of:

1) their high growth rate and primary productivity (Pomeroy, 1969) along with the large biomass and high productivity of epiphytic communities supported by seagrass leaves (Hopper and Meyers, 1967; Jones, 1968; Humm, 1969; Penhale, 1977);
2) the detrital food chain (Fenchel, 1977), providing nutrients not only for associated estuarine biota, but to reef communities offshore (Randall, 1965) and to the abyssal regions of the open ocean (Menzies et al., 1967);
3) the sediment stabilizing effect of the roots and rhizomes of the plants (Scoffin, 1976), and their retardation of currents, which increases sedimentation of organic and inorganic material around the plants (den Hartog, 1977);

4) their roles as nurseries and shelters for estuarine biota;
5) their combination of extensive coastal waters worldwide (den Hartog, 1977).

The high productivity of seagrasses implies a high nutrient demand (McRoy and McMillan, 1977); this in turn implies trace metal cycling in seagrasses. Seagrasses such as shoal grass, *Halodule wrightii* Aschers; eelgrass, *Zostera marina* L.; and turtle grass, *Thalassia testudinum* K.; play an important role in heavy metal cycling. Driftmeyer et al. (1980) found that eelgrass constituted the largest biological reservoir in selected metal budgets. Schroeder and Thorhaug (1980) concluded that marine angiosperms take up substances through roots and leaves, with significant translocation occurring in either direction (root to leaf, leaf to root), depending on uptake site and concentration. Parker (1962, 1963) concluded that reservoirs of selected heavy metals existed in the top few cm of sediment in a seagrass community and that seagrass leaves were capable of removing trace metals from the surrounding water column (Parker, 1966). Brinkhuis et al. (1980) demonstrated that translocation of cadmium between roots-rhizomes and leaves occurred in both directions. Montgomery et al. (1978) showed rapid uptake of certain metals by leaves of *Thalassia*. Jagels (1963) also concluded that *Thalassia* leaves were important uptake organs for selected anions and cations.

Plant material and water samples were analyzed for copper during a 6 mo period in order to trace copper cycling and distribution within the estuarine system. Copper was chosen because of its metabolic importance in low concentrations and toxic effects in high concentrations (Rains, 1976).

MATERIALS AND METHODS—The study site was a subtidal mud flat in the Indian River, near Link Port, Florida at 27°32′ N., 80°21′ W. (Fig. 1); water depth is approximately 0.5 m; mean tidal range is 0.15 m (Montgomery et al., 1979); and sediment is muddy sand (Thompson, 1976).

An initial sample of *Halodule* was collected on 30 April 1979. This sample consisted of 2 grabs from a modified posthole digger (van Breedveld, 1975), which took a 15 X 15 X 15 cm plug of grass and sediment. Sediment was separated from plant samples by filtering through a 4 mm plastic sieve, and washing with seawater. PVC disposable gloves were worn when handling the plants. Grass samples were then transferred to clean polyethylene bags and stored on ice until transported to the laboratory. On 3 July 1979, 10 posthole grabs were analyzed for variation of copper content between samples. A low coefficient of variation (10%) was found between the three plant parts (leaves, rhizomes, roots). The number of posthole samples taken for each subsequent sampling effort was then reduced to provide 2.0 g dry wt of each plant part per sample. Later samplings were on 7 August, 13 September, 27 September, 11 October, and 25 October 1979.

Water was sampled from the surface directly over the *Halodule* bed, and at grass leaf level, using a modification of the method of Hucks et al. (1978). Sediment pore water samples from depths of 2, 10, and 20 cm were collected using the system of Montgomery et al. (1979). Samples for redox potential (Eh), pH, and salinity determination were kept from contact with air. For collection, the sampling line was immersed to the desired depth in the water being collected, or connected to the sampling lines of an *in situ* pore water sample. The sample bottle, covered with a plastic bag when open for collection, was rinsed with the first 50 ml of sample, the rinsate discarded, and collection was resumed after addition of 1.0 ml nitric acid (HNO_3 Ultrex, Baker Inc.) to the sample bottle. Prior to each cruise, filters were loaded into a filter assembly in the laboratory under a laminar air flow hood. Each component part of the system, and all labware used in this study, was cleaned by first soaking in a dilute (1% in water) Triton X-100 soak at 70°C for 2 to 3 da, and then by soaking in dilute aqua regia (3:1:1, $HCl:HNO_3:H_2O$) for 3 to 8 hr

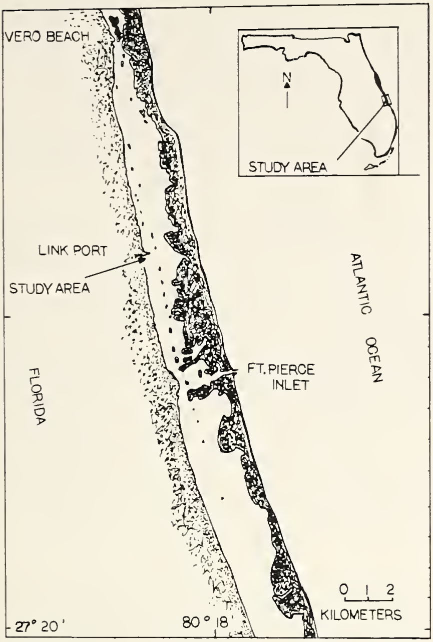

FIG. 1. Sample area.

(French, 1980). Salinity was measured by an optical refractometer (American Optical). A YSI Model 51A O_2 meter measured dissolved oxygen before and after the sampling routine. Two hr after collection, the redox potential (Eh) and pH of each sample were measured in the laboratory in an argon purged glove box using a Corning digital 110 pH meter with an Orion combination redox specific ion electrode and a microprobe combination pH electrode.

Grass samples were separated into leaves, rhizomes, and roots in the laboratory. Epiphytic growth was removed from leaves by hand using PVC gloves. The separate plant parts were placed in individual plastic bags, and stored at −5°C. The plant parts were leaves; the green erect shoots branching from the rhizomal axis; rhizomes; the pale brown, horizontal shoots; and roots; the unbranched, darker colored parts originating at the rhizomal internodes. Frozen parts were defrosted, the wet weight recorded, and dried at 60°C to constant weight in individual beakers. After 13 September 1979 all samples were lyophilized. After drying, the samples were homogenized with an alumina-coated mortar and pestle and refrigerated in polyethylene vials. One g. (dry wt) aliquots were wet-oxidized using concentrated nitric acid (Ultrex, Baker Inc.) in 40 ml Teflon digestion bombs (Bombco, Inc.). French (1980) reported in detail the use of these bombs, with emphasis on digestion specifications and safety procedures. The digestate was diluted to 15 ml and stored in polyethylene vials.

All plant digestates were analyzed directly on Perkin-Elmer Model 306 (PE-306) atomic absorption spectrophotometer (AAS) equipped with a deuterium arc background corrector. Appropriate blanks were analyzed, along with standard reference materials SP (Sea Plant) — M-1, and NBS Orchard Leaves (Lot No. 1571).

Measurements of Cu in the Sea Plant homogenate from an interlaboratory study (Fukai, 1977) ranged from 3.3 ± 0.1 μg/g to 21.4 ± μg/g. The Sea Plant reference material, analyzed with field samples from 3 July, 7 August, and 13 September, showed a mean Cu concentration of 12.1 ± 0.4 μg/g, with a precision of 3.2%. Analysis of NBS Orchard Leaves for copper with field samples from 26 September, 11 and 25 October resulted in a mean value of 11.4 ± 0.2 μg/g with a precision of 1.8%. The reported Cu content (12.0 ± 1.0 μg/g) was not significantly different ($p < 0.05$) from previously obtained values.

Water samples were directly analyzed using a "matrix matching" method (Montgomery and Peterson, 1980), on a PE-603 AAS equipped with a HGA-2100 graphite furnace, and ramp programmer.

RESULTS AND DISCUSSION—Increases in the spring-summer values for Cu were seen in all 3 plant parts on 13 September 1979. Eleven days prior to this sampling, Hurricane David passed over the sample site. The increases in Cu content of the plant coincided with an increase in dissolved Cu in surface and water at the grass leaf level, and in pore waters (Table 1). Short-term decreases in dissolved oxygen (DO), temperature, salinity, pH, and an increase in Eh were measured after the storm's passage (Fig. 2).

Copper concentration in *Halodule* leaves was nearly double on 13 September 1979 from the spring-summer mean of 3.7 ± 0.9 to 6.9 ± 0.3 μg/g. The concentration increased by a further 46% to its final concentration of

TABLE 1. Tabulated data for copper concentrations in plant water samples. ND = Not detectable.

Sample Date (1979)	Plant Samples (μg/g Cu dry weight)		
	Leaves	Rhizomes	Roots
30 Apr.	3.8 ± 1.4	2.2 ± 0.1	1.86 ± 0.1
3 July	3.5 ± 0.4	1.4 ± 0.5	5.4 ± 0.5
7 Aug.	3.8 ± 0.8	2.6 ± 0.9	4.9 ± 0.5
13 Sept.	6.9 ± 0.3	7.2 ± 0.3	6.9 ± 0.6
27 Sept.	8.0 ± 0.9	3.8 ± 0.4	6.9 ± 0.2
11 Oct.	8.7 ± 0.1	3.9 ± 0.5	7.7 ± 0.1
25 Oct.	10.1 ± 0.4	5.4 ± 0.6	7.3 ± 1.0

Sample Date (1979)	Water Samples (μg/1 Cu)				
	Relative Depth		Sediment Pore Waters		
	Surface	Grass	2 cm	10 cm	20 cm
30 Apr.					
3 July	ND	0.5 ± 0.2	ND	ND	ND
7 Aug.	ND	ND	0.8 ± 0.1	1.4 ± 0.6	ND
13 Sept.	1.5 ± 0.1	1.9 ± 1.2	1.4 ± 0.3	1.3 ± 0.9	1.2 ± 0.9
27 Sept.	ND	ND	ND	ND	ND
11 Oct.	ND	ND	ND	ND	ND
25 Oct.	ND	0.8 ± 0.1	ND	ND	0.6 ± 0.1

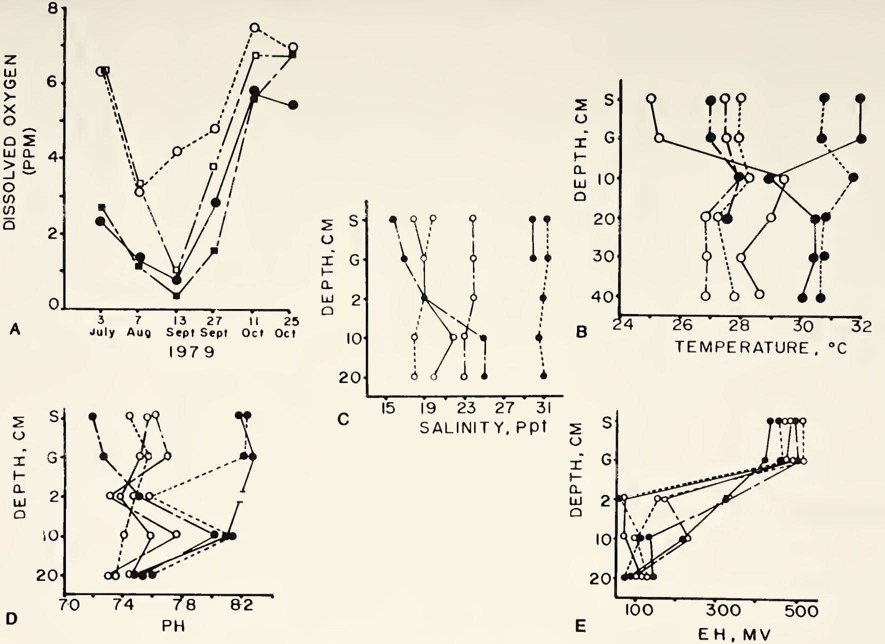

FIG. 2. Hydrographical data: A — Dissolved oxygen in surface water ●———● 0900h and ○– – –○ 1100h and at grass leaf level ■— — —■ 0900h and □– – –□ 1100h; B — Temperature °C; C — Salinity, ppt; D — pH; E — Eh, mv. S and G are surface water and water at grass leaf level respectively. 3 July ●———●; 7 Aug. ●– – – –● ; 13 Sept.●— — —● ; 27 Sept. ○———○ ; 11 Oct. ○— — —○; 25 Oct. ○— — —○

10.1 ± 0.4 μg/g by 25 October. Rhizomes increased in Cu content from a spring-summer mean of 2.1 ± 0.5 μg/g to 7.2 ± 0.3 μg/g on 13 September 1979. A decrease by 26 September to 3.8 ± 0.4 μg/g was seen, and this concentration remained constant until a slight increase was measured on 25 October (Table 1). Copper concentration in roots showed a 66% increase from spring to summer and then increased a further 41% on 13 September and remained constant until the end of the study.

Pulich et al. (1976) found that Texas populations of *H. wrightii* varied in Cu content in leaves and roots during the growing season. However, the magnitude of increases in Cu content in all 3 parts of our *Halodule* samples from 13 September 1979 shows that the increases cannot be attributed solely to part of the annual cycle.

The mass balance of μg Cu in plant part/g plant, as opposed to μg Cu/g plant, shows that the initial uptake of Cu is by the leaves, which show an increase from 1.0 μg Cu leaf/g plant on 7 August 1979 to 1.8 μg Cu leaf/g plant on 13 September (Fig. 3). The rhizomes must rapidly store the accumulated Cu, as an increase occurred from 1.0 μg Cu rhizome/g plant on 7 August to 3.4 μg Cu rhizome/g plant on 13 September. Copper in *Halodule* roots did not increase until 1 mo after the storm. This increase continued to 25 October, when the concentration of 3.2 μg Cu root/g plant was almost twice that of 27 September. One month after the storm, the Cu was translocated to the roots. These observations correlate with the decreases in leaf and rhizomal Cu. As the rhizome in seagrasses is a storage organ with a waxy cuticle that prevents exchange of materials with sediment pore waters (Schroeder, 1975), movement of Cu to organs (such as roots) where exchange can occur is understandable.

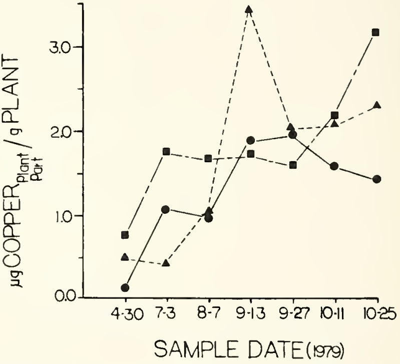

FIG. 3. Mass balance of copper (μg Cu plant part/g plant) in *Halodule*. ●——● = Leaves, ▲– –▲ = Rhizomes, ■—·—■ = Roots.

Dissolved Cu in water increased from pre-storm (7 August 1979) to post-storm (13 September) samples (Table 1). Water column samples (surface and grass-leaf level) were 3 times greater than the minimum detectable concentration (MDC) of 0.5 μg/1 on 13 September. On the next sampling date, these waters were less than the MDC. Pore water at the 2 cm depth showed an increase in dissolved Cu by a factor of 2 in pre- and post-storm samples, with a subsequent decrease on 27 September to below 0.5 μg/1. The lower values in the sediment pore water samples on 27 September and the 2 following samples support the hypothesis of Cu translocation to *Halodule* roots. The increase of Cu in roots (μg Cu roots/g plant) did not occur until 1 mo after the hurricane, when dissolved Cu in sediment pore waters was low in concentration, relative to 11 da after the hurricane.

The storm imposed an increased oxygen demand on the water over the shallow, near-shore sample site (Fig. 2[A]). The lower values in the early morning (0900) reflected the grasses' respiratory activity during the night. The oxygen produced by the plants later in the morning increased the DO at both surface water and water at grass leaf level.

Measurements of temperature and salinity profiles showed the system's resiliency after a major storm Fig. 2 B and C. A decrease in surface water temp of 4°C is noted from 7 August to 13 September. Pore waters (10-40 cm depth) also showed a decrease in temperature on these dates. A further decrease of surface water temperature to 25°C on 27 September was not seen in the sediment pore waters. A slight increase in the 10 and 20 cm depth samples occurred. Though cooler, the profile of 25 October is similar to that of 7 August. This indicates a restoration of the pre-storm temperature profile. A lowering of surface water salinity from 31 ppt on 7 August to 16-17 ppt on 13 September occurred. This was due to fresh water input from the storm. A lag was seen in the decrease in sediment pore water salinity, as seen between 13 September and 11 October (25 ppt and 18 ppt at 10 cm depth). A profile similar to that of 7 August was re-established by 25 October.

After changes in pH and Eh in sample site waters on 13 September, profiles resembling those of 7 August returned by 25 October (Fig. 2 D and E). Surface water pH decreased from approximately 8.2 on 7 August to 7.2 on 13 September. Sediment pore waters showed a lag in this decrease. Although the values are lower, the profile of 25 October resembles that of 7 August. Short-term increases in Eh occurred. Measurements of pore water and water Eh values showed an increase of approximately 50 mv from 7 August to 13 September. The 2 cm depth sample had a short-term increase of approximately 200 mv by 13 September. The Eh profile similar to that of 7 August resulted on 25 October 1979.

Data on biomass are in Fig. 4. Dry weight (g/m^2) is of the whole plant above and below the sediment surface. The maximum biomass for the 6 mo sampling period was in August (245 g/m^2) and the minimum was on 27 September 1979. The decrease in standing crop from the August maximum also shows the storm's effect on the shoal grass. Standing crop as measured

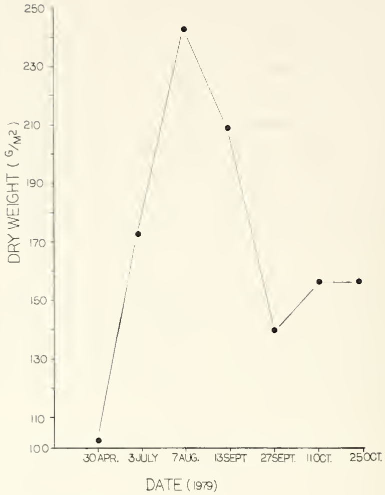

FIG. 4. *Halodule wrightii* biomass (g/m²).

by Gilbert and Clark (1981) in the Banana River, Florida shows a seasonal maximum in September 1975.

The change of physico-chemical parameters because of the storm is one explanation for the increase in dissolved Cu in the surface and sediment pore waters. For example, the pH decreased from approximately 8.2 before the storm to 7.2 after the storm. Increased turbidity caused by the storm's action would affect a lowering of *Halodule*'s production through decreased illumination and lead to a build-up of CO_2 and a lowering of the pH. Excess humic acids from the storm's runoff could reduce the pH, and decay of organic material and grass detritus leading to the production of CO_2 or H_2S could also reduce the pH. At the lower pH, copper will have an increased solubility, probably occurring as the dissolved species $CuCo_3^0$ and $CuOH^+$ (Stumm and Morgan, 1981).

Redox potentials are important in characterizing marine environments (Whitfield, 1969). The decomposition of organic matter in the runoff caused by the storm could mobilize Cu bound by the plant. Soluble organo-copper complexes could form from this material (deGroot and Allersman, 1973). Copper has greater solubility in oxidized waters as compared to moderately reducing environments. In pore waters with lower redox potentials, copper sulfide, which tends to be insoluble, is formed (Hem, 1975). The storm's wind and wave action on the shallow *Halodule* beds could have resuspended insoluble Cu from shallow depths in sediment to the more oxidizing environment, of the surface water. The increase of approximately 200 mv in the 2 cm sediment pore waters on 13 September indicates that sediment was more oxidized during this period.

In a similar study, Huggett and Bender (1976) concluded that an increase of Cu in the Chesapeake Bay estuarine system after Tropical Storm Agnes (1972) was due to sediments and organic material containing Cu transported to the estuary by the storm's rain and runoff. This could explain the increases in Cu in waters and plants in our study, and post-storm pH and Eh conditions favorable to dissolved inorganic species and soluble organo-copper complex made the Cu more available for uptake by *Halodule*.

We found that *Halodule* will accumulate Cu made available by the perturbation of a major storm, and retain this metal by translocation from leaves to roots. As seagrasses are important directly to estuarine organisms for food, and indirectly to other communities, an increase in Cu in the *Halodule* system at a future date would make this metal potentially available to other organisms. Long-term monitoring of Cu content in these near-shore systems will directly detect any excess in the Cu budget in the systems.

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Academy Symposium

COMPUTER SIMULATION OF LIGHT ATTENUATION

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ABSTRACT: *A computer simulation model developed to study light attenuation in the ocean was applied to clear, medium turbid and turbid waters under diverse conditions. The model theory is based upon multiple small angle scattering of photons by hydrosols and molecules, and includes the effects of absorption. Results show a striking difference between clear and turbid waters and demonstrate the strong dependence of transmittance on turbidity.*

THE subject of underwater optics is of importance to those interested in oceanic photosynthesis and its effects on various biological problems. A discrete particle simulation technique, developed for modeling non-linear processes in physics (Hogan and Stetson, 1975) was used to investigate downward photon scattering in ocean systems. The technique is presented as a simple alternative to the Monte Carlo method (Kattawar et al., 1973 and Gordon, 1976). The technique has also been successfully applied to study reaction-diffusion in chemical and biological systems (Stetson et al., 1976 and Hogan and Stetson, 1982). The model simulated Rayleigh scattering of photons by water molecules, Mie scattering off hydrosols, and included radiant energy losses due to absorption. The scattering of photons at angles of 0° to 90° was investigated, but the contribution due to backscattering was not included. The parameters for the model were chosen to be in agreement with data gathered in the St. Lucie Inlet and surrounding coastal waters. Downward scattering was calculated as a function of photon wavelength, the size and density of suspended particulate matter, and the depth in the medium.

METHODS— The model assumed that for radiance calculations, photons can be treated as discrete "particles" and that multiple small angle scattering predominates. Consequently, the Mie and Raleigh scattering functions were treated independently and sequentially, the incident radiation was taken to be plane electromagnetic waves with random polarization, and the effects of interference were not included. The model simulated smooth ocean surface water with the solar angle at the zenith, and did not consider the effects of ocean floor albedo. The suspended particulate matter was assumed spherical and the distribution was assumed homogeneous and isotropic. The simulation was for ocean surface waters, the average temperature of the medium was 20°C, and the refractive index was taken to be 1.34 for the ocean water and 1.20 for the particles.

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The basic simulation scheme had 4 sequential portions. An initial uniform distribution of one million monochromatic photons was incident upon the test volume of the computer simulated ocean water. The photons travelled downward in steps of 1 m, $\triangle z = 1$, and the resulting angular distribution was calculated. At each step the photons were first Mie scattered by the hydrosols then Rayleigh scattered by the water molecules. Next, the fraction of photons lost due to absorption was subtracted from the total number remaining at that depth and a new angular distribution was calculated for the photons. The process was repeated until the photons reached a depth of 10 m. The simulation was performed for 5 wavelengths covering the visible spectrum using the clear ocean model, and for blue light using the medium and turbid ocean models.

The simulation technique used statistical weights to determine relative effects of the attenuation processes. Three cross section ratios specify these processes (Kattawar et al., 1973). The ratio CRS determines the probability that a photon is Rayleigh scattered instead of Mie scattered, the ratio CMS determines the probability that a photon is Mie scattered instead of Rayleigh scattered, and CTS determines the probability that a photon is scattered instead of being absorbed upon collision. Table 1 gives these probabilities as a function of wavelengths for clear ocean water and gives them for blue light in medium turbid and turbid waters. Water is considered clear when approximately 50% or less of the incident light is absorbed in the first meter of penetration. The water is medium turbid for approximately 60% absorption and turbid for approximately 70% absorption.

TABLE 1. Cross section ratios for photon scattering as a function of wavelength and turbidity.

Wavelength (nm)	Water	CRS	CMS	CTS
400	Clear	.328	.672	.555
460	Clear	.218	.782	.514
480	Clear	.190	.810	.491
500	Clear	.166	.834	.447
550	Clear	.120	.880	.332
650	Clear	.065	.935	.080
460	Medium	.079	.921	.380
460	Turbid	.045	.955	.270

The Mie scattering (hydrosol) portion of the simulation was performed by first multiplying the total number of photons by CMS to determine what fraction of the downward flux underwent particle scattering. The angular distribution of the photons thus scattered was calculated using a random walk probability function. The probability that a photon will be scattered through an angle Θ is given by:

$$P(\Theta) = (2\ \pi\sigma)^{-1/2} \exp(-\ \Theta^2/2\sigma)$$

where σ is the mean-square scattering angle. It has been shown (Modesit, 1971) that

$$\sigma = N\pi\ zR^2(n-n_o)^2/n_o^2$$

where N is the number density of particles per m^3, z is the distance in m travelled per step, R is the avg particle radius in m, n is the refractive index for the particles, and n_o is the refractive index for the ocean water. By varying these parameters in σ it is possible to simulate different types of ocean water.

The Rayleigh scattering (molecular) portion of the simulation was performed by multiplying the number of photons by CRS to determine the fraction that are scattered by the water molecules. The angular distribution of these photons was calculated using the scattering function for seawater given by Morel (1974). The function coefficients bring into account the strong dependence of scattering on wavelength, which is inversely proportional to the fourth power of the wavelength. Morel's function also accounted for the effects of pressure on the relative index of refraction by shifting the exponent from 4.0 to 4.32.

Losses due to absorption were incorporated by multiplying the number of photons scattered into each angular direction by CTS. When the statistical weight of a photon became less than 10^{-6} it was subtracted from the distribution of downward flux and was no longer considered.

This completed 1 iterative cycle. The resulting angular distribution of photons was calculated and a graph of the intensity versus angle was printed. The next step was to increment the depth by one meter and then repeat the entire process. Using this procedure the photons were followed to a depth of 10 m.

The parameters for the model were chosen to agree with data gathered in the mouth of the St. Lucie Inlet and surrounding coastal waters (Florida Institute of Technology, 1981). The logic behind the choice of parameters was to provide a simulation study of the waters near the inlet prior to the 1981 dredging project. Secchi disk measurements and submarine photometer readings indicated that these waters could be considered medium turbid, on the average, for the period of the study. The parameters chosen were consistent with data gathered in the Ft. Pierce Inlet (Thompson et al., 1979. For comparison, the computer model was run using cross section probabilities for clear, medium turbid and turbid waters. Other parameters chosen for this model were:

Average temperature = 20°C
Average particle radius = 3×10^{-6}m
Average particle density = 2×10^{7}m^{-3}

A convenient feature of this model is that these parameters can be easily modified to simulate other experimental data.

RESULTS—Fig. 1 shows results for the clear water model where photon intensity is plotted against scattering angle at a depth of 10 m. The 5 curves

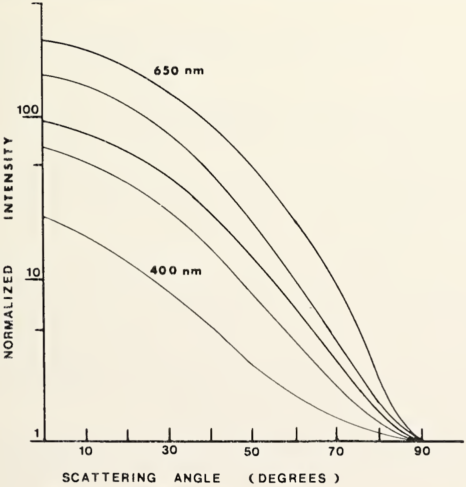

FIG. 1. Photon intensity vs. scattering angle at a depth of 10 m in clear ocean water. The curves are for wavelengths of 650 nm, 550 nm, 500 nm, 460 nm, and 400 nm.

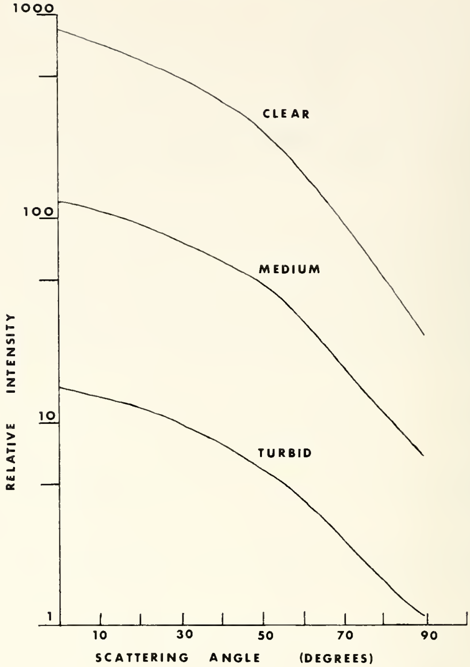

FIG. 2. Photon intensity vs. scattering angle at a depth of 6 m. The results are for clear, medium turbid and turbid waters at a wavelength of 460 nm.

represent wavelengths of 650 nm, 550 nm, 500 nm, 460 nm, and 400 nm. This clearly demonstrates the dependence of attenuation upon wavelength. Data were normalized to the scattering at 90° to illustrate the differentiation at small angles and plotted on semi-log paper.

Fig. 2 shows the dramatic differences among the clear, medium turbid and turbid waters. Results are for blue light (460 nm) at a depth of 6 m, where the relative intensity is plotted against scattering angle. It is evident that transmittance decreases as the turbidity increases. Photon intensity was decreased by a factor of 0.14 for medium turbid water and by a factor of 0.02 for turbid water, compared to clear water at the same depth. The model also indicated that maximum transmittance shifted towards the red end of the spectrum as turbidity increased.

Fig. 3 illustrates the sensitivity of the model to changes in particle density and particle radius. Curve A is the same as the one shown in Fig. 2 for medium turbid water at a depth of 6 m. Curve B is obtained when the particle density was changed from 2×10^7 to $4 \times 10^7 m^{-3}$, and curve C is obtained

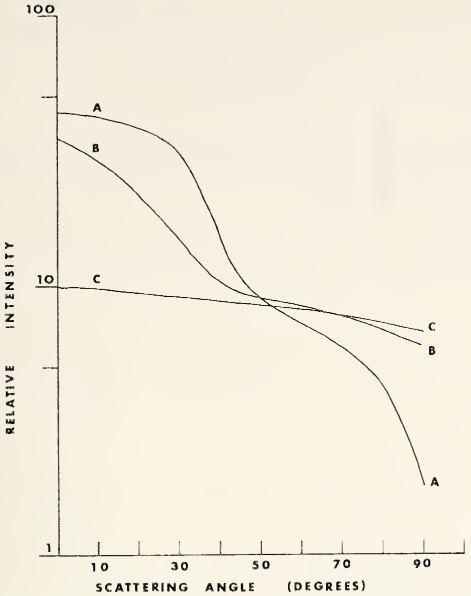

FIG. 3. Photon intensity vs. scattering angle at a depth of 6 m. For curve B the particle radius was twice that for curve A and for curve C the particle density was doubled. Results are for medium turbid water at a wavelength of 460 nm.

when the particle radius was changed from 3 x 10^{-6}m to 6 x 1-$^{-6}$m. All other parameters were held constant for these comparisons. Results indicate that when either the density or radius was increased, the photon intensity decreased at small scattering angles and increased at larger angles.

CONCLUSION — Absorption dominates the attenuation of electromagnetic radiation except in the narrow range of the visible spectrum. Scattering becomes an important contribution to the total attenuation in the 350 nm to 500 nm range. In clear ocean water approximately 50% of the radiation is absorbed in the first m of penetration as a result of the extinction of the infrared. Maximum transmission is at about 465 nm (blue-green) in clear water and shifts to higher wavelengths (about 550 nm) in turbid water. This observed shift results because the suspended particulate matter both absorbs and scatters shorter wavelengths more than longer wavelengths. Another contributing factor is that dissolved organic material selectively absorbs shorter wavelengths. The final result is that maximum transmittance shifts towards longer wavelengths in the more turbid coastal waters, and total transmittance decreases.

Future investigations should include additional computer simulations on light attenuation as new data become available on particle size, density and turbidity in the St. Lucie Inlet and surrounding coastal waters.

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Academy Symposium

THE OCCURRENCE OF A TOXIC DINOFLAGELLATE IN THE INDIAN RIVER SYSTEM

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Abstract: *References to the toxic dinoflagellate,* Gonyaulax monilata *Howell, in the Indian and Banana rivers are compiled from published and unpublished sources. The inability of researchers to find motile cells for extended periods indicates that benthic resting cysts or hypnozygotes may be the only source for the seed population.*

Gonyaulax monilata Howell was originally described from red tides in the Banana and Indian rivers in 1951 (Howell, 1953). Howell reported that water discoloration was caused by large numbers of dinoflagellates, but no great quantity of fish were killed. *G. monilata* was taken "from all stations in the Indian and Banana Rivers" but no reference was given for specific station locations. Although there have been numerous "red tides" and fish kills in this lagoonal system over the last 30 yr, there is no published record of *G. monilata* presence. I compiled the references to this species which to date were only in laboratory notes (C. Down, Brevard County Health Department, B.C.H.D.) or in theses (Modert, 1977; Trees, 1977; Donnelly, 1980) from Florida Institute of Technology, in addition to the paper by Howell (1953). Additional comment is made regarding the absence of this species in the estuary.

TABLE 1. Occurrence of motile *Gonyaulax monilata* in the Indian River lagoon system.

Date	Location, Comment and Source	Cells/Liter	Dissolved Oxygen (ppm)	Temp. (°C)	Sal. ($^0/_{00}$)
Aug-Sept 1951	"Indian & Banana Rivers: (discolored water, minor fish kill). Howell, 1953	"Large Nos."	-	30-34	18-32
12 July 1977	Between Eau Gallie & Melbourne Causeways (No fish kill). Trees, 1977	8.9×10^5	-	31.5-32	32.0
27 July 1977	Melbourne Beach Pier (no fish kill). Modert, 1977	1.7×10^6*	6.0	29.5	30.5
9 Sept 1977	W-Side of I.R., Port St. John (1000's dead fish) B.C.H.D. (unpubl.)	"Bloom"	"Depleted"	-	-
6 Sept 1979	Scattered from Horse Cr. to Fisherman Point (no fish kill) Donnelly, 1980	$< 1.0 \times 10^3$	4.8-7.6	24.5-30.0	16-21

*Conservative estimate from 4 cells/chain.

Table 1 is a compilation of the published and unpublished references to *G. monilata* in the Banana and Indian rivers along with the available hydrographic data and maximum cell concentrations. Except for the station at Port St. John and the unidentified stations of Howell (1953), the locations of these records are indicated in Fig. 1. The only specific reference to fish kills were by Howell and by B.C.H.D.; however, there is not sufficient evidence to implicate *G. monilata* as the direct cause of death. The fish kill could have been due to oxygen depletion. *G. monilata* has also been associated with fish kills along Florida's west coast (Williams and Ingle, 1972), in Pensacola and Mobile bays (Perry et al., 1979) and the Galveston, Texas area (Wardle et al., 1975).

Interestingly, *G. monilata* blooms have had mixed effects in regards to fish kills. For example, Wardle et al. (1975) reported unusual numbers of dead and moribund marine organisms on Galveston Beach associated with a *G. monilata* bloom (1.88×10^6 cells$\cdot l^{-1}$, 31°C, 33‰), while no mortalities were reported by Perry et al. (1979) for Mississippi Sound (1.65×10^7 cells$\cdot l^{-1}$, 30.0-30.8°C, 24-26‰). Both blooms occurred in open waters,

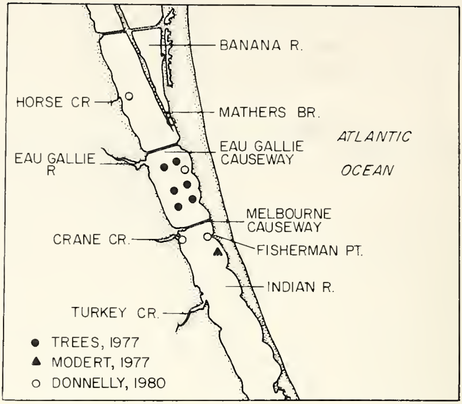

FIG. 1. Distribution of motile *Gonyaulax monilata* cells near Melbourne, Florida.

unlike the lagoonal system of the Indian River. The concentration of *G. monilata* cells (Table 1) reported by Modert (1977) would appear to be sufficient to cause a fish kill though none was reported.

After nearly a year of sampling without collecting any motile cells of *G. monilata*, Donnelly (1980) found low concentrations (Table 1) following the passage of hurricane David in early September 1979. In a 6-mo. study in the same area, David (1978) also did not find motile *G. monilata* cells. This apparent lack of motile cells for months (if not years) supports the belief that benthic resting cysts or hypnozygotes described by Walker and Steidinger (1979) are the only source for the seed population of *G. monilata* blooms in the Indian River lagoon system (Owen and Norris, 1982). Walker and Steidinger (1979) proposed that cysts in Florida waters act as seed beds to initiate *G. monilata* blooms.

The contribution and concern of the late Cherie Down for the Indian River are appreciated as are the efforts of P. J. Donnelly, C. W. Modert, and C. C. Trees. Mary Ann Nelson drafted the figure and Thelma Coughlin typed the manuscript.

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Academy Symposium

SEDIMENT IN SEAGRASSES NEAR LINK PORT, INDIAN RIVER, FLORIDA

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ABSTRACT: *Grain size analyses have been made for 34 samples of the upper 5 cm of sediment cores from seagrass beds. Sieves were used for gravel and sand; the SEDIGRAPH was used for silt and clay.* THALASSIA *(13 samples),* HALODULE *(3),* SYRINGODIUM *(3) and bare sand areas (15) within seagrass beds were sampled in the summers of 1979 and 1980. Generally, these sediments are sands, with small admixtures of gravel, silt and clay. The average particle size is about 0.25 mm with grain size modes at 0.3 and 0.1 mm. These sediments are poorly sorted (large standard deviation), positively skewed (excess fine particles) and are leptokurtic (excessive peakedness). Sand content is greater than 90% by weight, and is mostly quartz. Gravel consists of carbonate shells and shell fragments. Mineralogy of the silt fraction is not known, and the clay is judged to be mostly kaolinite from crystal shapes seen in transmission electron microscopy. Comparison of sediment from different species of seagrasses to bare sand areas reveals little difference in terms of grain size characteristics. There are no data available to document seasonal differences. There is a significantly higher content of silt ($\bar{X}$ = 1.33%) in* THALASSIA *sediments than in nearby sandy areas ($\bar{X}$ = 1.01%). Comparison of silt grain size data (62.5 to 3.9 μm) shows that the most abundant particle sizes present in* THALASSIA *sediment are between 15-30 μm. Particle size distribution of silt in nearby sandy areas shows less concentration in this range. Preliminary results from late summer sediment trap measurements give a particle flux of 10-20 g m^{-2} day^{-1} during ordinary weather, which doubled during passage of storm DENNIS. It is not known how much of this flux has come from local resuspension of sediment particles.*

SEAGRASSES apparently trap fine-grained sediments (Ginsburg and Lowenstam, 1958). This has been reported for high-latitude *Zostera* beds and detrital silicates in southeastern Alaska (Nelson, 1970) and Chesapeake Bay (Orth, 1977); for lower latitude *Thalassia* and *Halodule* and silicates in Florida (Young and Young, 1978; Grady, 1981; Wolcott and Thompson unpubl. data); the Mediterranean *Posidonia* (Kikuchi, 1980); and low-latitude *Thalassia* and biogenic carbonate sediments in Buttonwood Sound, Florida (Lynts, 1966), the Florida reef tract (Swinchatt, 1965), Bimini (Scoffin, 1970), Alacrán Reef, Mexico (Hoskin, 1963) and Mahé in the Seychelles (Taylor and Lewis, 1970). Burrell and Schubel (1977) reviewed the general nature of sediments associated with seagrasses and the particle trapping process. Wanless (1981) discussed erosion and deposition in *Thalassia* beds of Key Biscayne, Florida, with emphasis on the vertical sequence of grain size for seagrass-accumulated sediment.

There are little data available on the geology, sediments, and specifically the sediment associated with seagrasses in the Indian River. Zimmermann (1980) reported grain size data for 6 cores from within a one-square-meter area of *Halodule* near Link Port. Gilmore (1977) described the environments of the Indian River and included a brief geological summary.

I compare grain size characteristics of the uppermost 5 cm of sediment from seagrass beds and immediately adjacent grass-free areas in the Indian River. As sediment supply, water depth, currents, wind and wave energy should be the same for grassy and sandy areas only a few meters from each other, any effects of suspended particle trapping by the seagrasses should be discernible in the size-frequency distributions of accumulated sediment. Measurements of wind speed and direction, suspended sediment concentration, and bed load transport were not made during this study. Water current velocity and direction were measured for brief periods of only a few hours. The dynamics of suspended sediment transport is beyond the scope of this study by design.

STUDY SITES—In 1979, samples were collected to characterize sediment for different species of seagrass. Sample sites (Fig. 1) were selected from relatively pure stands of each species of seagrass, each of which may be no larger than a few meters in any direction. Thompson (1976) made maps of seagrasses from aerial photographs for 73 nautical miles of the Indian River including the location of this study, and reported mixed species stands. Virnstein (pers. comm.) made detailed maps of seagrasses near Link Port, and found large areas of mixed species.

In 1980, samples were collected from *Thalassia* beds and grass-free areas within *Thalassia* beds to determine the grain size characteristics of sediment from each. For all sample sites, water depths were 0.5-1.0 m, and shore was within tens to hundreds of meters away. As seen from oblique, low-altitude aerial photographs, seagrass beds cover most of the visible bottom except for irregular, but east-west elongated grass-free patches. No bed forms were

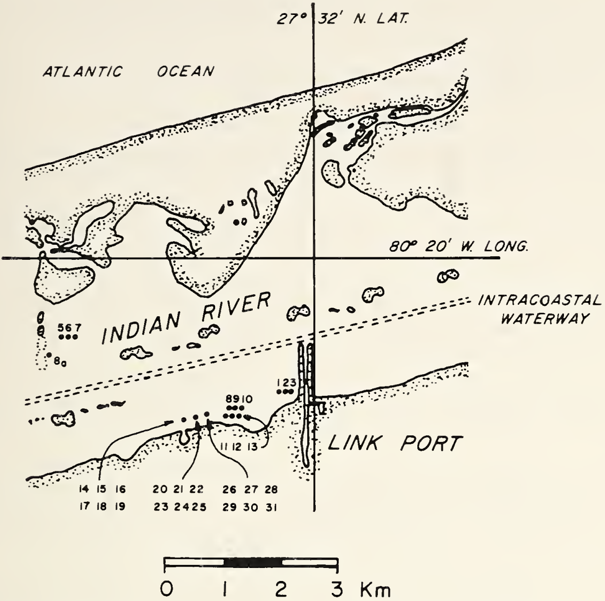

FIG. 1. Sample location map, Indian River, near Link Port, Florida. Link Port is in St. Lucie County, between the cities of Vero Beach and Fort Pierce, on Florida's east coast. Samples 32-34 were collected a few meters south of sample group 26-31. Sediment trap sites near sample group 14-19. Sample No. 4 was from an oyster bed, and is not included in this study. Modified from NOAA National Ocean Survey, Nautical Chart 11472, 1978.

seen in seagrass or sandy areas, however, sandy areas were slightly deeper, $\cong$ 0.1-0.3 m.

METHODS — Sediment was collected using a manual 9.5 cm ID PVC corer. The uppermost 5 cm of each core was stored wet and unpreserved in polyethylene bags.

Tidal range at Link Port is about 10 cm (Ned Smith, pers. comm.). Current velocity and direction in the seagrasses were determined by time-lapse photography of dye spots, using 35 mm camera and a tethered balloon. Three periods of current measurements were done, centering about midway between high and low water. Plastic sediment traps, (7 X 21 cm cylinders closed at one end), were deployed in arrays of 4 traps attached to aluminum supports. Horizontal spacing between each sediment trap and between each end trap and the vertical aluminum support tube was 15 cm. These traps conformed to the flume-tested design of Gardner (1980). The trap arrays were located in small (2-3 m) sandy areas within *Thalassia* beds (Fig. 1). The bottom of each trap was several cm above the water-sediment interface, and the open end was covered with a plastic cap before recovery. Traps were deployed in 3 periods of 8, 5 and 3 da duration (Table 3).

Each grass-sediment core was placed in a plastic bucket with about a liter of water and digested overnight with commercial bleach. Seagrass was removed and the sediment wet-sieved (62.5 μm openings). Retained particles were oven dried (95°C) and dry sieved at one half Φ intervals (Folk, 1970). The mud sized particles were allowed to settle, the supernatant water removed, and the mud was stored wet and unpreserved. Particle size analysis of mud was done by

SEDIGRAPH. Grain size descriptions were calculated from arithmetic-ordinate graphs using the formulae of Folk and Ward (1957). Size-frequency distributions were generated by plotting the weight percent of particles retained in each one half ϕ interval; points were plotted at the midpoint of each interval.

Sediment was recovered from each trap by washing onto tared glass-fiber filters. Water and salt were removed by suction, and the filters oven-dried at 95°C, and reweighed to 0.01 mg.

RESULTS AND DISCUSSION—Samples 1-13 and 32-34 were taken to characterize sediments from sandy areas and from each species of seagrass. Data for weight percent of major size classes, grain size name, and statistical descriptors are in Table 1. Size-frequency curves for selected samples from this group are in Fig. 2. Overall, these sediments are similar. Because seagrass trapping of particles is believed to occur in the mud-size range, samples 14-31 were taken to determine mud content and particle size distribution in the mud range for *Thalassia*-associated sediments. Data for these samples are in Table 2 and Fig. 3. Sediment flux data from the traps are in Table 3. Maximum flow velocity of dye-marked water in *Thalassia* beds was about 4 cm sec^{-1}, approximately parallel to the shoreline.

GENERAL SEDIMENT CHARACTERISTICS—Surface sediments from *Thalassia*, *Halodule*, *Syringodium* and bare sand areas near Link Port are similar in

TABLE 1. DESCRIPTIVE GRAIN SIZE DATA. GRAVEL >2.00 mm, sand 2.00 to 0.0625 mm, silt 62.5 to 3.9 μm, clay <3.9 μm, mud is silt plus clay. Name for grain size is from Folk, 1954, where SG = slightly gravelly, ms = medium sand, mus = muddy sand, VFS = very fine sand. Grain size descriptors are: M_z mean size in mm, δ_I is sorting (standard deviation), SK_I is skewness, K'_G is normalized kurtosis, mode is grain size in mm (Folk and Ward, 1957). All sample numbers (#) have a prefix of IR.

#	Gravel	Sand	Silt	Clay	Mud	Name	M_z	δ_I	SK_I	K'_G	Mode
	Halodule										
1	.3	93.6	.9	5.3	6.2	SG, MS	.24	1.66	+.53	.79	.3
2	0	95.0	1.1	4.0	5.1	MS	.24	1.06	+.49	.71	.3
3	0	94.2	0	5.8	5.8	MS	.25	2.03	+.58	.84	.3
	Thalassia										
8a	.5	82.5	7.0	10.1	17.1	SG, MUS	073	2.03	+.76	.87	.11
8	3.6	88.4	.5	7.6	8.1	SG, MS	.25	2.17	+.56	.83	.3
9	.9	92.7	.8	5.7	6.5	SG, MS	.21	2.00	+.61	.82	.3
10	1.2	92.7	.7	5.4	6.1	SG, MS	.25	1.90	+.56	.84	.3
	Sand areas in west Thalassia bed										
11	1.4	93.4	1.7	3.6	5.3	SG, MS	23	2.13	+.46	.66	.3
12	7.8	84.8	1.5	6.0	7.5	SG, MS	.3	2.35	+.27	.85	.3
13	.7	94.4	.7	4.2	4.9	SG, MS	.23	.80	+.37	.59	.3
	Sand areas in east sea grasses										
5	.4	92.5	1.2	5.9	7.1	SG, VFS	10	1.68	+.53	.91	.11
6	.2	93.5	2.3	4.0	6.3	SG, VFS	.10	.65	+.62	.76	.11
7	.1	92.5	2.1	5.2	7.3	SG, VFS	.10	1.18	+.53	.89	.11
	Syringodium										
32	6.79	88.26	.69	4.25	4.94						
33	5.49	90.75	1.05	2.70	3.75						
34	6.26	90.07	.75	2.90	3.65						

TABLE 2. Comparison by grain size for *Thalassia* associated and grass-free sediments.

	Thalassia Wt. %						Bare Sand Wt. %				
	Gravel	Sand	Silt	Clay	Mud		Gravel	Sand	Silt	Clay	Mud
Station 1											
14	2.14	92.97	1.36	3.51	4.87	17	1.46	94.67	.75	3.11	3.86
15	2.13	93.44	1.32	3.09	4.41	18	1.01	95.33	.84	2.80	3.64
16	2.43	92.70	1.53	3.32	4.85	19	1.61	94.95	.97	2.45	3.42
Station 2											
20	1.17	95.14	1.14	2.53	3.67	23	1.00	96.05	.82	2.12	2.94
21	3.53	91.46	1.28	3.73	5.01	24	4.48	92.50	.87	2.13	3.00
22	3.12	90.96	1.45	4.46	5.91	25	5.84	87.72	1.67	4.76	6.43
Station 3											
26	3.54	92.83	1.19	2.42	3.61	29	20.26	75.35	1.31	3.06	4.37
27	2.62	93.81	1.42	2.14	3.56	30	5.51	90.70	.68	3.09	3.77
28	3.18	89.51	1.24	6.05	7.29	31	7.68	87.86	1.18	3.26	4.44
n	9	9	9	9	9		9	9	9	9	9
Range	1.17-3.54	89.51-95.14	1.14-1.53	2.14-6.05	3.56-7.29		1.00-20.26	75.35-96.05	.68-1.67	2.12-4.76	2.94-6.43
x̄	2.65	92.54	1.33	3.47	4.80		5.43	90.35	1.01	2.98	3.99

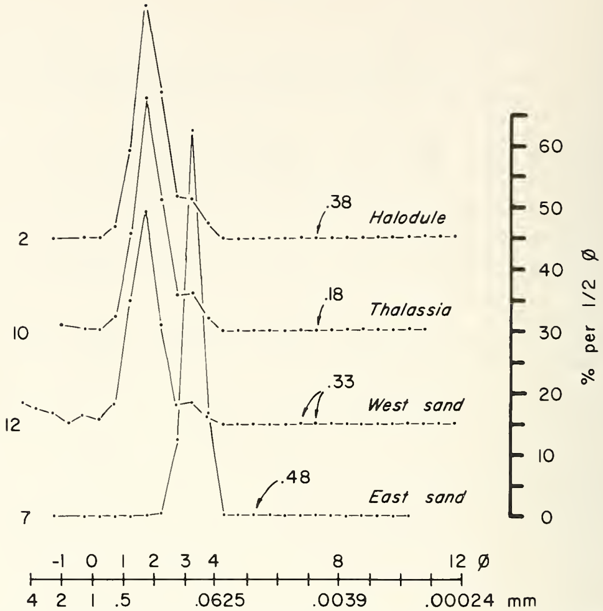

FIG. 2. Size-frequency curves for selected sediment samples. Ordinate scale at right; zero y-intercept for each sample at middle of sample number at extreme left. Number on flat portion of each curve in 4-12 ϕ range indicates maximum y-axis value for that part of the size spectrum.

terms of grain size. Quartz sand is the main component, averaging about 90% by weight. Grains of 0.3 and 0.1 mm are the most abundant, forming well-developed grain size modes (Fig. 2).

Particles of gravel size (> mm) are mostly mollusc shells, present in the range of 0-8 wt. percent. The size of the core segments analyzed (several hundred grams) was too small to identify grain size modes in the gravel fractions.

Mud content (particles < 62.5 μm) is 3-17 wt. percent. Young and Young (1978) reported an average of 12% mud in *Halodule* sediments at their Link Port study site. Coastal muds are mixtures of silt and clay (Picard, 1971). Mud fractions from sediments in the Indian River have a clay content which consistently exceeds silt, by weight percent (Table 1). This is true for mud fractions from both *Thalassia* and grass-free areas (Table 2) and thus the greater clay to silt content may not be due to a baffling effect of the seagrass.

Using the grain size names of Folk (1954), Indian River sediments are gravelly sands (Table 1). The mean particle size is near 0.25 mm. Average

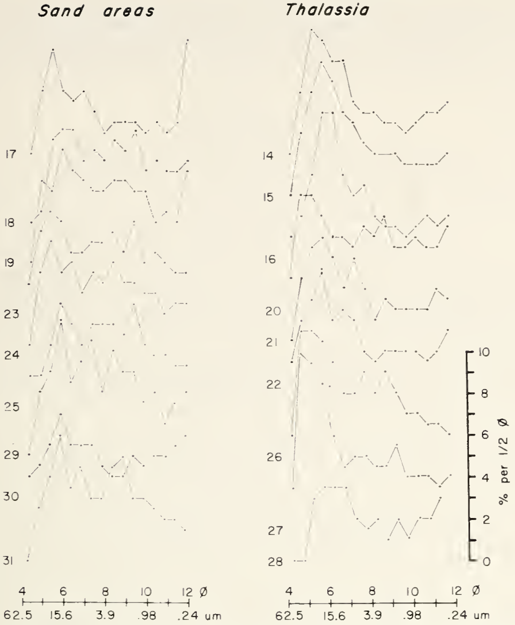

FIG. 3. Size-frequency curves for 9 samples from *Thalassia* and 9 from sandy areas within the *Thalassia* beds. These data are for the 4-12 ϕ part of each sample; gravel and sand components are not included in this figure. Ordinate scale as for Fig. 2.

sorting is poor, reflecting the gravel and mud components. Average skewness (symmetry of distribution) is positive, indicating an excess of fine particles. Average kurtosis indicates excessive peakedness, compared to a Gaussian distribution.

COMPARISON OF *Thalassia* AND GRASS-FREE AREAS — Many studies have reported fine-particle trapping by seagrasses, but as Wanless (1981) observed, no studies known to him had documented the specific influence of seagrasses on sediment texture or transport. Scoffin (1970, p. 270) reported that average silt plus clay content increased from 2.3% in bare sand, to 4.0% in sparse *Thalassia* and 14.6% in dense *Thalassia*, but station locations and the proximity of bare sand to seagrass stations were not given. Grady (1981, p. 340) reported that average silt plus clay content of sand flat sediments was 0.8% in contrast to 2.9% for seagrass sediments. Orth (1977) found a 1% silt plus clay content in 2 sand stations and 10% for 4 seagrass stations. Marshall and Lukas (1970, Tab. 3, p. 109) reported silt plus clay content for a grass-free area to be 5 ± 3% and with *Zostera* to be 14 ± 6%; however, water depths were not comparable.

TABLE 3. Particle flux measured by sediment traps on the margins of *Thalassia* beds, g m^{-2} day^{-1}. Asterisk indicates period of Hurricane Dennis, 17-18 August 1981.

Time	Site A	Site B
13-20 Aug. 1981*	31.4-38.1 $\bar{x}$ 34.4±3.1	No data
21-25 Aug.	13.7-32.3 $\bar{x}$ 20.1±8.4	17.3-19.9 $\bar{x}$ 18.4±1.1
26-28 Aug.	9.2-15.5 $\bar{x}$ 12.0±3.0	13.6-17.0 $\bar{x}$ 15.5±1.4

To evaluate the effect of fine-particle trapping by seagrass, grassy and grass-free environments are needed side-by-side, with the only variable being presence/absence of the grass. Three locations in the Indian River, 250 m apart, were chosen for this comparison (Fig. 1, Table 2). The only significant difference found between these sediments is that *Thalassia* sediments contained more silt ($\bar{X}$ = 1.33%) than the grass-free areas ($\bar{X}$ = 1.01%) as determined by t-test, p = 0.01.

The increased silt content in *Thalassia*-associated sediment from the Indian River is shown in Fig. 3. Data in Fig. 3 are for the mud fractions of each sample, with a y-axis expansion of 5x. The main features of size-frequency curves for *Thalassia* sediment are the dominant grain size mode between 15-30 μm, and the general and gradual decrease in particle abundance with decreasing size. In contrast, size-frequency curves for sediment from grass-free areas within the *Thalassia* beds contain the 15-30 μm mode, but particle abundance tends to remain high with decreasing size. The process(es) responsible for this difference is not known. Mineralogy of the 15-30 μm silt is not known, but as the particles survived digestion in bleach, they are probably inorganic. A comparison of the number and distribution of grain size modes present in each of the 8 size classes between 4-12 ϕ revealed no difference for mud fractions of *Thalassia*-associated sediment (19 modes) and sediment from grass-free areas (22 modes). Most grain size modes occurred in the 15-30 μm size class for each of the 2 sediment types.

SEASONALITY—Seagrass blades may trap fine sediment by reducing current velocity, permitting gravity settling of suspended particles; absence of seagrass should eliminate the settling effect. Eiseman and Benz (1975) reported seagrass biomass to be about 200 g m^{-2} in summer, decreasing to 0-50 g m^{-2} in winter. This seasonal decrease in seagrass biomass might lower the amount of trapped sediment. I have no data to evaluate this idea. Lynts (1966) reported no sediment grain size change between August and February for *Thalassia*-associated sediments in Buttonwood Sound, Florida.

PRELIMINARY SEDIMENT TRAP STUDY—The data in Table 3 show that particles do settle from suspension in seagrass areas. Local resuspension is probably the proximate source for particles settling in the traps (9-38 g m^{-2} day^{-1}) as there are no local rivers supplying suspended particles.

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INDIAN RIVER FOULING ORGANISMS, A REVIEW

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Abstract: *More than 72 species of fouling organisms are found in the Indian River. Most are of warm water affinity. Many species are seasonal, whereas others settle throughout the year. Species distribution patterns show that the species composition of the fouling community changes north of the Ft. Pierce Inlet. The Ft. Pierce Inlet area is dominated by stenotopic colonial forms, whereas eurytopic solitary forms dominate the areas north of the inlet. Differences are attributed to increasing environmental stresses on the organisms at locations away from the inlet. Disturbances also influence the fouling community. Most members of the Indian River fouling community are filter feeders, and the suspended materials they feed on may be cycled through the community several times before falling to the bottom as sediment. Fouling communities are an important agent for converting suspended material to bottom sediments.*

Earliest references to Indian River region fouling organisms are studies by Richards and Clapp (1944) done in the Ponce de Leon Inlet area north of the Indian River and barnacle collections made in the Ft. Pierce area (Pilsbry, 1953). Several studies have been done in Biscayne Bay (Weiss, 1948; Smith et al., 1950; Moore and Frue, 1959), south of the Indian River, where the fouling community is somewhat similar to that of the Indian River. Since 1976 I have published several papers concerning Indian River fouling organisms and fouling communities (Mook, 1976, 1977a, 1980, 1981a, 1981b). In this paper I list the fouling organisms found in the Indian River and review the fouling studies that have been done in the region. Areas where considerable work needs to be done are suggested.

Methods — Species lists of fouling organisms were made from species observed during studies done at Link Port, Ft. Pierce and Vero Beach (Mook, 1976, 1980, 1981a) and from collections made in the St. Lucie Inlet, Ft. Pierce Inlet, Sebastian Inlet, Eau Gallie and Haulover Canal during the summers of 1976 and 1977. Other contributions were made from studies by Winston (1977; 1982), Hettler (1978) and from observations made in the Intracoastal Waterway (J. K. Reed, pers. comm.).

Results and discussion — Seventy-two species of fouling organisms have been observed in the Indian River. These species are of tropical and warm temperate affinities (Mook, 1976, 1980; Winston, 1977) and have been collected in a wide range of habitats (Table 1). This list is probably not complete, and as more studies concerning fouling organisms are done, I would expect this list to expand. Groups of fouling organisms that need more taxonomic study are the hydroids, polychaetes and sponges. The Indian River contains as many or more fouling species than many other estuaries and bays reported in the literature (probably considerably more if hydroids, sponges and polychaetes were identified) (Table 2). The Indian River does not contain a large amount of natural substratum for encrusting organisms. Lack of natural substratum may be a limiting factor for fouling organisms. During the last several decades, many man-made structures have been erected in the lagoon, increasing available space for settlement of fouling organisms. Whether this increase in substrate has allowed more species to enter the Indian River is not known.

TABLE 1. Fouling species recorded in the Indian River. Key: 1—St. Lucie Inlet, 2—Ft. Pierce Inlet, 3—Link Port, 4—Vero Beach, 5—Sebastian Inlet, 6—Eau Gallie area, 7—Haulover area, 8—Observed along rocky ledge of Intracoastal Waterway south of Vero Beach (J. Reed, pers. comm.), 9—Winston (1977), 10—Winston (In press), 11—Banana River (Hettler, 1978).

Organism	Note
ASCIDIANS	
Ascidia curvata	1
Ascidia nigra	1,2
Ascidia sp.	1
Botrylloides nigrum	1,2,5
Botryllus planus	1,2,5
Botryllus scholosseri	1,2,3,5
Cavelina oblonga	1,2
Cavelina picta	1,2
Didemnum candidum	1,2,3,5
Diplosoma fragile	1,2,5
Diplosoma macdonaldi	1,2,3,4,5
Distaplia bermudensis	1,2
Eudistoma capsulatum	1,2
Eudistoma olivaceum	1,2
Ectienascidia turbinata	1,2
Molgula occidentalis	3,6
Molgula manhattensis	3,6
Polyandrocarpa tincta	1
Polyclinum constellatum	1,2
Pyura vitata	1
Styela plicata	1,2,3,4,5
Symplegma viride	1,2,3,4,5
Trididemnum savignii	1,2,3,4,5
ANTHOZOANS	
Leptogorgia virgulata	8
Lophogorgia hebes	8
Oculina varicosa	8
Phyllangia americana	8
Telesto riisei	1,2
HYDROIDS	
Eudendrium sp.	2
Obelia sp.	3
Plumularia sp.	2
Thyroscyphus sp.	2
BRYOZOA	
Alcyonidium polypylum	10
Beania hirtissima	10
Beania klugei	10
Bowerbankia sp.	9
Bugula neritina	1-5
BRYOZOA (cont'd)	
Bugula stolonifera	3
Conopeum seurati	3
Conopeum tenuissimum	2-4
Crisia elongata	10
Electra bellula	9
Hippoporina verrilli	2
Nolella stipata	10
Saviguyella lafontii	10
Schizoporella floridana	1-4
Scruparia sp.	2
Scrupocellaria regularis	10
Victorella pavida	10
Watersipora subovoidea	1,2
Zoobotryon verticillatum	2,3
SPONGES	
Halochondria sp.	3
Haliclonia sp.	3
Cliona sp.	2,3
MOLLUSKS	
Anomia sp.	4
Brachiodontes sp.	4
Crassostrea virginica	All stations
Lopha frons	1,2,3,4,5,6
Modiolus sp.	11
Volsella sp.	
CRUSTACEA	
Balanus amphitrite	1,2,3,4,5,6,7
Balanus eburneus	1,2,3,4,5,6,7
Balanus tintinablium	1,2,5
Balanus trigonus	2,3
Chthamalus sp.	2
Tetraclita squamosa stalagtifera	2,5
Corophium lacustre	2,3,4
Ericthonius sp.	2
POLYCHAETA	
Branchiomma nigromaculata	3
Hydroides sp.	All stations
Sabellarid tubes	2
Spirorbis sp.	All stations

TABLE 2. Number of fouling species found in various estuarine locations as compared to the Indian River.

Location	No. Species	Reference
Indian River	72	This study
Beaufort, N.C.	68	McDougall (1943)
Biscayne Bay	42	Weiss (1948)
Washington State (Admirality Inlet)	24	De Palma (1976)
Woods Hole	54	Osman (1977)
Monterey Harbor	70	Haderlie (1968)

The Indian River contains many biotopes. It is adjacent to the Florida Current, and it is located in a transition zone between the warm temperate and the tropical zones (Gilmore, 1977; Gore, 1972). These factors are responsible for the large number of fish (Gilmore, 1977), decapod (Gore, 1972) and foraminifera (Buzas and Severin, in press) species found in the lagoon and are probably also responsible for the large number of fouling species living in the Indian River.

Some species of Indian River fouling organisms settle throughout the year, whereas others are either warm or cool season settlers (Mook, 1976). For example, the barnacles, *Balanus eburneus* and *B. amphitrite* and the serpulid polychaete, *Spirorbis* sp. settle throughout the year in the Indian River, whereas the bryozoans, *Bugula neritina* and *B. stolonifera* settle only in abundance during cooler months. The colonial ascidian, *Symplegma viride* and the sabellid worm, *Branchiomma nigromaculata* are most abundant in the summer. Year-to-year temperature and salinity fluctuations in the Indian River are large (Mook, unpubl. data), thus it is assumed that variations in settlement patterns of various species of fouling organisms are also high because environmental factors affect the establishment of fouling organisms (Mook, 1976).

Initial colonizing species do not seem to affect the ultimate species composition of Indian River fouling communities. Recent studies (Mook, 1981a) have shown that when test plates were submerged at different times of the year to assure different initial species settlement, communities were the same after a year of submergence. Studies done in temperate areas (Sutherland and Karlson, 1977; Osman, 1977) indicate that the historical effect of initial settlers is evident for a much longer period (several years) than in the Indian River. Differences between the Indian River fouling community and those in other studies may be due to the fact that settlement is occurring throughout the year in the Indian River, whereas in more temperate areas, settlement is restricted more to warmer months.

Temperature and salinity vary significantly more in areas more distant from the Ft. Pierce Inlet (Vero Beach and Link Port) than at the Ft. Pierce Inlet (Mook, 1980). Along this same gradient of physical variability, a corresponding decrease in number of fouling species was observed. For example, Mook (1980) noted 32 species of fouling organisms at the Ft. Pierce

Inlet, 21 at Link Port and 14 species of fouling organisms at Vero Beach. Further up the lagoon at Eau Gallie, Hettler (1978) observed only 9 species of fouling organisms suggesting this reduction of fouling species continues northward, possibly because environmental variability increases northward in the lagoon. Whether this increase in variability is due to increasing distance from inlets, changing climatic conditions or a combination of both has not been determined. Other estuarine studies have found a decrease in the number of species with increasing environmental variability (Sanders et al., 1965; Boesch, 1972; Jackson, 1972) and it appears that Indian River fouling organism distribution follows the same pattern. Young and Young (1977) also noted an increase in environmental stress from south to north in the Indian River, but did not note a corresponding decrease in soft bottom species numbers.

Sanders (1968) suggested that in areas of higher physical stress, species selection was determined largely by physical variables, whereas in areas of lower physical stresses, biological interactions have a greater effect on species selection. These factors also appear to influence species selection in the Indian River. For example, the Ft. Pierce Inlet area fouling community is dominated by stenotopic colonial forms, whereas areas away from the Inlet appear to be dominated by eurytopic solitary forms (Mook, 1980). Eurytopic solitary forms can survive in the inlet area because they are found there in small numbers, but they are generally outcompeted by the colonial forms (Jackson, 1977). Conversely, the eurytopic forms are found in greater abundance in areas remote from the inlet because they are not outcompeted by the more spatially limited colonial forms which can survive only in the more environmentally stable inlet area.

Other factors besides environmental variability affect what fouling species can be found in various areas of the Indian River. Mook (1977a) found that the gastropod *Modulus modulus* limited the survival of fouling organisms in seagrass beds, while a few meters away where seagrass was absent *Modulus* had little effect. The amount of disturbance (i.e., predators) that a fouling community is subjected to can affect not only the number of species found in the community but also the type of species present (Mook, 1981a). For example, when large fish were prevented from grazing on the fouling community, the solitary ascidian, *Styela* dominated the fouling community and prevented barnacles from surviving. In fouling communities that were not protected from predators, barnacles were among the most numerous forms (Mook, 1981a).

Competition for space has been considered to be a limiting factor for fouling organisms (Dayton, 1971). Recent studies have suggested that competition for food may also be an important competitive mechanism (Buss, 1979), at least when fouling organisms are in dense assemblages (Buss and Jackson, 1981). Whether competition for food is an important competitive mechanism in the Indian River is not known. More diverse fouling communities probably utilize the suspended material food resource more efficiently than less diverse communities, because food particles are passed from species to species before finally falling to the bottom (Mook, 1981b). Indian River fouling assemblages are able to effectively filter suspended particles at least as small as 1 μm from the water column (Mook, 1981b), generating 20-50 g m^{-2} of fecal pellets daily (Hoskin, 1980). The large amount of fecal pellets suggests that the local fouling community acts as an important agent converting suspended material to bottom sediments where these materials can become available to benthic feeders. Studies are underway to determine how efficiently fouling assemblages utilize the suspended material as an energy source. The fouling community also acts as a food source for many estuarine forms. For example, the sheepshead, *Archosargus probatocephalus*, has specialized dentition for feeding on fouling communities (Mook, 1977b). Broken barnacle fragments resulting from sheepshead feeding on fouling communities make up a sizable fraction of some sediments (Hoskin, 1980).

Because fouling communities are affected by environmental stress, and because fouling communities can be grown on any hard substratum and be transported to other areas or to a laboratory, they have potential as a tool for assessment of water quality changes (Beak et al., 1973). Before fouling communities can be used as a tool for water quality assessment in the Indian River, more studies will have to be done so that community changes caused from normal environmental changes can be separated from changes caused by man-made stresses.

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SEASONAL VARIATIONS IN THE HEAT ENERGY BUDGET OF THE INDIAN RIVER LAGOON, FLORIDA

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Abstract: *Meteorological records and water temperatures are used to describe annual variations in the heat budget of the Indian River lagoon, on the Atlantic coast of Florida. In the summer of 1979, water temperatures varied 1-2°C about the seasonal norm over time scales of about 1 wk. Heat stored in the lagoon was highly correlated with net insolation, net outgoing longwave radiation and sensible heat fluxes. In the winter of 1979-80, warming and cooling cycles varied temperatures ±3-4°C about the norm, and the storage term was significantly correlated with only the sensible and latent heat fluxes.*

The conditioning of lagoonal waters by air-estuary heat energy exchanges is important in ecological studies, as well as in physical and hydrographic investigations. Energy fluxes explain heating and cooling cycles over a wide range of time scales. Intense heating or cooling at a particular location can result in thermal stratification or vertical overturning, respectively, which in turn can decouple or homogenize upper and lower parts of the water column through effects on vertical mixing. A stratified water column may exhibit quite different circulation patterns in upper and lower layers. Furthermore, this same stratification can inhibit the vertical flux of oxygen, for example, and encourage an oxygen depletion in the lower layer.

The specific processes through which warming and cooling occur are well known, and are summarized by the heat budget equation:

$$Q_t = Q_s + Q_m + Q_v + Q_e + Q_h + Q_b,$$

where Q_t is the storage term (the net effect of heating and cooling processes), Q_s is heating by net insolation, Q_m is the water-sediment conduction term, and Q_v represents heating by advective processes. Q_e and Q_h are the latent and sensible heat flux terms, and Q_b represents cooling by net outgoing longwave radiation. The magnitudes and relative importance of these terms are not well understood, largely because they are so highly variable in space and time.

For the most part, energy budget studies conducted in marine settings have been restricted to the very longest time scales and largest space scales. Investigations by Budyko (1956) and Malkus (1962), for example, have revealed annual patterns for entire ocean basins, continents or bands of latitude, using all available ship data or weather station observations grouped into monthly means. A slow net heating or cooling, however, can occur from a slight imbalance in the individual processes listed above, and temporal variability of these terms is generally over time scales much shorter than those defined by monthly averages. Specifically, heat fluxes occurring in response to passing weather systems, and varying over time scales on the order of 1 or 2 wk may be the primary driving force for a much more gradual energy gain or loss as well. Thus, it is important to focus upon the more rapid heating and cooling cycles by conducting investigations characterized by relatively high frequency sampling. This is especially true in the case of coastal lagoons. The shallow waters of these estuaries are particularly responsive to variations in air temperature, humidity, wind and cloud cover in the overlying atmosphere.

A series of field studies designed to describe the energy budget of the Indian River lagoon over short and intermediate time scales was initiated in the winter of 1977-78 and continued in the summer of 1979 and the winter of 1979-80. The primary objective of the program was to document the magnitude and relative importance of the various heat flux processes. Individually, results of these field studies characterize energy exchanges within a given season. In this paper, results are integrated to produce an improved understanding of the annual cycle of local heat fluxes in lagoonal waters along the east coast of Florida.

OBSERVATIONS—In each field study, meteorological records were assembled to provide a data base necessary to evaluate the heat fluxes associated with each term of the heat budget equation. Water temp were recorded to provide the data base required to verify calculations. Weather data were obtained with a Climatronics Corporation Weather Station about 200 m from the study site in the Indian River lagoon (Fig. 1). The study site itself was a shallow seagrass flat (27°32'N, 80°21'W), approximately 12 km north of the Fort Pierce Inlet.

Daily accumulations of incoming solar radiation (insolation) were obtained with a pyranometer having a spectral response between 0.35 and 1.15 micron (μ), a peak sensitivity at 0.85μ, and an accuracy of ±5%. Relative humidities, accurate to within 2%, were calibrated with sling psychrometer data collected throughout the study. Air temp records were digitized at hourly intervals to the nearest 0.6°C and calibrated with the dry bulb readings of the psychrometer. The temp data are accurate to within 0.6°C. Wind speed was sensed with a 3-cup anemometer, accurate to within ±1 cm/s. However, hourly values were estimated from an analog record to the nearest 45 cm/s (1 mile/hr)—a procedure which suppressed considerable gustiness at times.

All calculations involved 24-hr accumulations or averages to minimize effects of spatial gradients between the weather station and the study site, and because the time scales of interest were on the order of 1-2 wk. The effect of daily averaging, combined with the accuracy of the meteorological data, resulted in an accuracy of ±5 W/m² in the calculated energy fluxes.

The study area was a seagrass flat, containing beds of *Halodule wrightii* and *Syringodium filiforme*. Water depths in the area were generally 100-150 cm. The dominant M_2 tidal constituent amplitude was 10 cm in this part of the lagoon; nontidal processes varied water levels by an additional ± 10 cm. The Atlantic Intracoastal Waterway borders the study area to the east. The longchannel tidal excursion in the waterway locally is 4.7 km. The study area is approximately 12 km from the Fort Pierce Inlet, and the flood tide did not bring water this distance into the lagoon against the net southerly outflow.

Environmental Devices Corporation Type 109 temperature recorders were maintained to provide a temperature record used to verify temperature changes simulated by a computer model. Bihourly averaged bottom temperatures were digitized from the recording film by the manufacturer to the nearest 0.1°C, with an accuracy of ±0.2°C according to instrument specifications. Analytical methods used to convert weather records into heat energy fluxes have been discussed extensively in previous papers (Smith 1981a, 1981b, 1982a, 1982b).

METEOROLOGICAL SETTING—Results of summer and winter heat budget studies of the Indian River contrast sharply, due to the distinctly different meteorological conditions affecting the study area at these times of yr. In summer months, maritime tropical air covers the study area for weeks at a time, and weather patterns tend to be much more stable. In winter months, cold fronts moving down the Florida peninsula at approximately weekly intervals replace maritime tropical air with continental polar or continental arctic air. To put the results of the field studies in perspective, climatological data from the Cape Kennedy Air Force Station were used to construct annual curves of pertinent meteorological variables based upon multi-yr (1950-66) means (Environmental Data Service 1968). Data were collected approximately 110 km from the study site (Fig. 1), but patterns are probably representative of conditions along the 195 km length of the Indian River.

The dominant controlling force for the annual variation in weather generally, and for seasonal differences in air-estuary heat energy exchanges in particular, is the annual cycle of energy received from the sun. Multi-yr monthly means are shown at the top of Fig. 2 for Cape Kennedy Air Force Station. Average daily accumulations of insolation range from approximately 160 W/m² in December and January to about 280 W/m² in May. The amount of energy available for heating the lagoon is decreased by surface reflectivity, but the annual pattern should be similar.

Outgoing longwave radiation is dependent upon the absolute temp and radiative properties of the surface of the lagoon. But the net outgoing longwave radiation is determined by making corrections for counter radiation from within the atmosphere. Thus, both cloud cover and water vapor pressure data in the lowest layers of the atmosphere are important in correcting estimates based upon the Stefan-Boltzmann equation alone. Fig. 2 reveals little variation in daily mean cloud cover from 1 mo to the next. The averages may mask considerable day-to-day variability, however, especially in winter, when skies clear following the passage of a cold front. The only

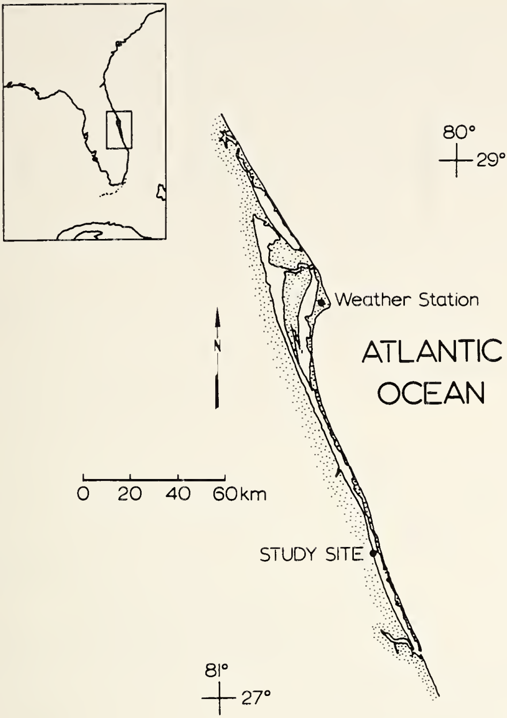

FIG. 1. Location of the site of the winter 1979-80 and summer 1979 heat energy exchange studies, and of the Cape Kennedy Air Force Station.

variation indicated by the monthly means is a slight increase in summer, when warm, moist maritime tropical air encourages greater cumulus development. The annual curve constructed from the vapor pressure data indicates a maximum of 28.5 mb in July and August. This, coupled with the increase in cloud cover, has an inhibiting effect upon outgoing longwave radiation and tends to counter the effect of a higher surface temperature in summer months.

When effects of frontal passages are averaged out, the annual progression of air temperature is similar to that of insolation, although there is an approximately 2-mo lag of the meteorological seasons behind the astronomical seasons. The 17-yr record from the Cape Kennedy weather station indicates a mean January temperature of 15.8°C, and a mean August temperature of 27.2°C—the annual minimum and maximum, respectively. The flux of sensible heat is determined by the water-air temperature dif-

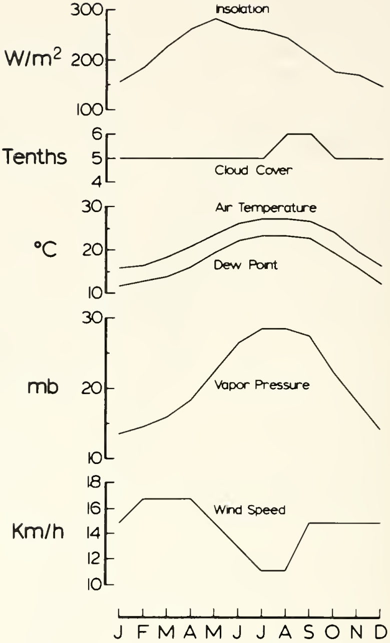

FIG. 2. Multi-year (1950-66) mo mean weather data from Cape Kennedy Air Force Station (See Fig. 1 for location of weather station).

ference, with wind speed playing an important ancillary role. Multi-year monthly average water temperatures are not available for the Indian River.

As noted above, vapor pressure traces out an annual curve similar to that of both air temperature and dew point temperature. Since the saturation vapor pressure approximately doubles with every 10°C increase in air temperature, it follows that the vapor pressure deficit in summer increases significantly, even though air and dew point temperatures track nearly evenly throughout the year. In fact, the average vapor pressure deficit is about 5 mb in winter months, while in summer it increases to approximately 16 mb.

Finally, the annual cycle in wind speed, shown at the bottom of Fig. 2, includes maximum values in late winter and early spring, and a minimum in mid summer. Because wind speed appears in the empirical expressions for both sensible and latent heat fluxes, it follows that these processes will be enhanced in winter months, when water-air temperature differences are greatest, and inhibited in summer, when the vapor pressure deficit is greatest. Thus, wind effects tend to amplify seasonal differences in the sensible heat flux and diminish seasonal differences in latent heat fluxes.

Results—Table 1 summarizes results of the Indian River heat energy exchange work by combining statistics computed from data collected during the summer of 1979 (Smith 1982a) and the winter of 1979-80 (Smith 1982b). Energy flux values are presented to the nearest 1 W/m², even though this is within the precision of the calculations. Mean values provide an appropriate starting point, although they mask temporal variability—which may be considerable—over time scales of up to several wks. In both summer and winter field studies, long-term net storage was essentially zero. By centering studies in time around mid winter or mid summer, an excess of cooling or warming in the early part of the study was cancelled by a net energy gain or loss during the latter part of the study period. Standard deviations, however, indicate that considerable variability exists about the mean. Thus the mean is not necessarily representative of conditions on any given day. This appears to be particularly true in winter months, when frontal passages effect periods of pronounced warming and cooling.

The 2 radiative terms are markedly different in both mean and standard deviation from summer to winter. Net insolation is larger in summer months, when the number of daylight hours is greater and zenith angles are higher. The mean daily net insolation in the winter study is 75% that calculated from summer data. This is in good agreement with the value of 67% obtained from climatological data for the area (Environmental Data Service 1968). Apparently, day-to-day variations in cloud cover increase from summer to winter, as the standard deviation increases from 74 to 88 W/m². The somewhat higher standard deviation in winter may reflect variations in cloud cover preceding and following frontal passages. The net outgoing longwave radiation term shows less seasonal variation in the mean, and the slight difference in standard deviation may not be real, given the precision of the calculations.

The average evaporative heat loss in winter of −121 W/m² is only 62% of the value derived from the summer data. The much lower vapor pressure deficit is only partially compensated by stronger winds. The standard deviation is greater by a factor of two, however, as evaporation is alternately enhanced with the arrival of continental polar or arctic air, then inhibited as maritime tropical air returns to the Atlantic coast of South Florida.

The sensible heat flux is a cooling process in both winter and summer months. The difference in mean values is relatively slight, but the standard deviation is over 5 times greater in winter, again due to the effects of frontal passages. In winter, the average water-air temperature differences was +1.4°C (water warmer), though the range was from +7.9 to −4.6°C. Further, during an average day, air temperatures rose to between 1° and 2° above the temperature of the lagoon (Smith 1982c). It summer months, the water temperature remains above the air temperature both over the course of an average day and from 1 da to the next. The water-air temperature dif-

TABLE 1. Statistical properties of local heat flux terms computed for the Indian River lagoon for the winter and summer studies. Mean and standard deviation (SD) are in Watts/m². Positive and negative values indicate fluxes into and out of the water column, respectively. Multilinear regression correlation coefficients less than 0.23 are not significant at the 95% confidence level.

				Correlation Coefficients				
Term	Season	Mean	SD	Q_m	Q_h	Q_e	Q_b	Q_s
Storage, Q_t	winter	+3	156	+0.03	+0.87	+0.84	−0.20	+0.16
	summer	0	73	−0.16	+0.44	+0.21	−0.59	+0.63
Net Insolation, Q_s	winter	+236	88	−0.18	−0.14	−0.33	−0.36	
	summer	+316	74	−0.34	+0.18	−0.44	−0.62	
Net Longwave Radiation, Q_b	winter	−74	6	−0.56	+0.07	−0.13		
	summer	−61	3	−0.04	−0.65	−0.00		
Latent Heat Flux, Q_e	winter	−121	94	+0.15	+0.82			
	summer	−194	45	+0.33	+0.41			
Sensible Heat Flux, Q_h	winter	−41	71	−0.15				
	summer	−54	14	+0.38				
Water-Sediment Conduction, Q_m	winter	+3	18					
	summer	−8	5					

ference during the mid summer study averaged +3.6°C, with a smaller standard deviation.

The conductive exchange of heat between the water column and the underlying sediments appears to be slight in both winter and summer months. Differences in mean values may not be real, given the precision of the calculations, but values are consistent with the phase lag of the annual temperature curve in sub-bottom layers. Again, the larger standard deviation in winter months is a logical result of the greater day-to-day variation in water temperature produced by frontal passages.

The matrix of multilinear regression correlation coefficients on the right side of Table 1 summarizes the interrelationships of local heat flux processes with each other and with the storage of heat in the water column. Of particular interest are values along the upper 2 lines, which may be interpreted in a cause-and-effect sense as the processes responsible for warming and cooling in winter and summer months. For winter data, only sensible and latent heat fluxes correlate significantly with the storage term. Both correlation coefficients are in excess of +0.800, suggesting that an alternation of warm, moist air with cool, dry air has a dominant effect upon the winter heat budget, and thus explains a substantial fraction of the variance of the storage term.

In summer months, the picture shifts significantly. Results indicate that 3 processes are correlated significantly with the storage of heat in the water column. The highest correlation coefficient is calculated for the storage and net insolation terms. The correlation coefficient for the net outgoing radiation term is only slightly less, but the small standard deviation for this term suggests that in this case the correlation coefficient is strictly a measure of similarity, rather than an indication of how important this process is in explaining warming and cooling. A highly variable storage of heat in the water column cannot be a response to a process which itself varies only slightly. The storage and sensible heat flux terms are also correlated at a significant level, and it appears that the sensible heat flux plays a significant role both in countering the long-term effects of warming by absorbed insolation and in explaining some of the day-to-day variability.

In summer months, the latent heat flux is not correlated significantly with the storage term. Evaporation is the principle cooling process — over 3 times greater than that resulting from the net outgoing longwave radiation — but with a persistence of maritime tropical air over the study area the evaporation is more constant. The relatively slight variation is poorly correlated with the day-to-day change in the storage term.

At both times of year, the correlation of the storage and water-sediment conduction terms is insignificant. Both studies suggest near-zero correlation coefficients, and the negative value obtained from the summer data casts further doubt upon the physical reliability of the calculations.

Some of the other, apparently significant correlation coefficients are difficult to interpret in a physically realistic way. For example, it is not clear why there should be any sort of a consistent relationship between the net outgoing longwave radiation term and the water-sediment conduction term in winter mo, especially when there is apparently no correlation under summer conditions. The most probable explanation lies in the likelihood that these values can arise by chance even from 2 data sets which are in fact unrelated.

Discussion — The integration of climatological data with results from summer and winter studies makes it possible to postulate annual cycles for air-lagoon heat energy exchanges. An annual progression appears to exist in 3 quite different ways, however. There is a variation in the magnitudes of several of the individual terms, a variation in the standard deviations about the seasonal means, and a distinct difference in the correlation with the storage term from winter to summer months.

Two processes reach obvious extremes in summer months: heating by absorbed insolation is at its annual maximum, and cooling by evaporation is greatest at that time of year. The remaining 3 terms have such small amplitudes that the significance of the extremes is as difficult to determine as are the exact times at which they occur. From the available data, it appears that the heat energy loss by water-sediment conduction is greatest in summer, while heat losses by sensible heat fluxes and net longwave radiation are least.

Higher radiative energy losses in winter could be a result of the correlation for counter radiation used in the calculations (Swinbank, 1963), as well as characteristically clearer skies. The surface temperature is used with a proportionality factor in the empirical expression to represent the moisture in the lower atmosphere that is absorbing outgoing longwave radiation and re-radiating a portion of it back downward. Lower surface temperatures in winter, implying a lower moisture content of the atmosphere overlying the lagoon, would result in a smaller correction and a greater net outgoing longwave radiative energy loss. This is consistent with the annual curve constructed from monthly mean vapor pressures (Fig. 2).

The standard deviations computed from the daily mean fluxes show a seasonal variation of their own, and raise questions concerning the representativeness of seasonal means for conditions on any given day. In general, the standard deviations reflect the persistence of a particular meteorological situation. Summer months are characteristically stable in terms of synoptic scale weather patterns affecting South Florida. Thus the standard deviations calculated for all processes are relatively small for the summer study, and the seasonal means are more representative of heat energy fluxes on a particular day.

Finally, a distinct seasonal shift occurs in the processes responsible for the day-to-day variations in the amount of heat stored in the water column. In winter months, the alternation of air masses enhance sensible and latent fluxes, and together these explain nearly all of the day-to-day warming and cooling. Essentially the same result was obtained from a winter study of

Laguna Madre in Texas (Smith, 1981a). For summer conditions, the two radiation terms assume a greater importance, while the latent heat flux, although at its annual maximum, is poorly correlated with the storage term. Sensible heat fluxes remain important, but the correlation coefficient decreases to half the wintertime value. The summer situation appears to be one in which, on the average, heating by insolation is balanced by cooling in response to outgoing longwave radiation, evaporation and sensible heat flux. Day-to-day imbalances, however, result in the observed cycles of warming and cooling.

Hastenrath (1976) has investigated annual variations in heat energy exchanges for a study area just east of the Indian River lagoon — in the waters of the Gulf Stream at about latitude 30°N. A comparison of his seasonal curves for open ocean waters with results summarized here for Indian River waters brings out some interesting similarities and differences. First, by utilizing weather data recorded throughout the year, Hastenrath obtained an improved temporal resolution in his annual curves. As might be expected, the curves themselves do not trace out purely sinusoidal shapes. However, extrema occur in winter (December) and summer (June-July) mos. Thus, winter and summer studies are adequate for a crude approximation of the annual cycle. Second, the air-water exchange of sensible heat offshore is 180° out of phase with the pattern suggested by the Indian River data. The curve reaches an annual minimum in summer in Gulf Stream waters, while it passes through a relative maximum in the Indian River. This may be due to the greater responsiveness of lagoonal waters, or a result of the modification of air moving offshore in winter months.

Keijman (1974) demonstrated that meteorological data recorded some distance from a study site can be used to investigate the heat balance of a body of water and to reproduce cycles of warming and cooling. The study was based upon the equilibrium temperature concept, however (Edinger et al., 1968), and thus did not treat the separate heat energy exchange terms explicitly. The Indian River work may therefore be thought of as a logical extension of this work, because it utilizes off-site weather observations to investigate local heat flux processes individually. This appears to raise the possibility of conducting investigations of annual cycles in heat energy exchanges at several sites simultaneously. In each case, there would have to be only enough *in situ* water temperature data collected to obtain the appropriate empirical coefficients, and to verify the calculations to the desired accuracy.

The integration of results from seasonal Indian River heat budget studies, combined with the comparison of lagoonal and open ocean heat budget calculations, leads to several conclusions. It is apparent that aside from diurnal variations (Smith 1982c) the time scales of interest are those associated with the movement of meteorological systems — nominally 1-2 wks — and the annual march of the seasons. Furthermore, results show that the scatter about the annual cycle, at least, exhibits a distinct seasonality, resulting from equally distinct differences in the climate of South Florida during winter and summer months. Finally, one may conclude that results representing a particular time and place cannot be extrapolated in time to another season, nor in a spatial sense across the coastal zone. There are definite restrictions to the results obtained in these studies, however, it is likely that the patterns are generally applicable to estuarine systems for which the physical and meteorological settings are similar.

ACKNOWLEDGMENTS—George Kierspe, Lew Gilliland and Mark Sternberger assisted in collecting data, digitizing meteorological records, developing the computer program used to model heat energy exchanges, and plotting the results. Weather records were obtained through the National Climatic Center in Asheville, North Carolina. This is Harbor Branch Foundation, Inc., Contribution Number 275.

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REPRODUCTIVE BIOLOGY OF THREE SPECIES OF SEA ANEMONES FROM THE CENTRAL ATLANTIC COAST OF FLORIDA

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Abstract: *Reproductive biology of 3 species of sea anemones was studied over an 8 mo period in the intertidal zone along the central Atlantic coast of Florida.* Actinia bermudensis *on the north jetty at Fort Pierce Inlet spawned at the end of September 1977; planulae were brooded throughout the yr. The sex distribution of 82 animals examined was 41 females, 5 males and 36 without gonads.* Aiptasia pallida *from Sebastian Inlet spawned in September 1977 and possibly in March 1978; the skewed sex distribution of 134 animals examined was 34 females, 2 males and 98 without gonads.* Bunodosoma cavernata *from the south jetty at Jupiter Inlet spawned in October 1977; planulae were brooded throughout the yr. The sex ratio of 75 animals examined was closer to one-to-one (19 females, 29 males, 26 lacked gonads, and 1 hermaphrodite).*

Sea anemones occur in central Florida waters in variety and abundance, but surprisingly little is known of their reproductive biology. Some information may be gleaned from systematic works (McMurrich, 1889; Duerden, 1898, 1902), but in most cases this information is limited to descriptions of the reproductive state of a few specimens under systematic study. Accordingly, during a post-doctoral yr at Harbor Branch Foundation I examined the reproductive biology of 3 species of sea anemones from the Indian River and nearby coastal waters of central Florida.

Materials and methods—Nine to 13 (usually 12) individuals of *Actinia bermudensis* were collected on 7 occasions between 16 September 1977 and 21 June 1978 from the low intertidal zone along the north jetty at Fort Pierce Inlet. Twelve to 15 individuals of *Aiptasia pallida* were collected on 3 occasions between 20 September 1977 and 13 December 1977 from low intertidal rocks along the north shore of Sebastian Inlet. In 4 further collections made between 8 February 1978 and 6 June 1978, this number was increased to between 19 and 26. Between 11 and 15 individuals of *Bunodosoma cavernata* were collected on 6 occasions from 5 October 1977 to 24 May 1978, from the low intertidal zone on the south jetty at Jupiter Inlet. Additionally, 1 specimen was taken at Fort Pierce Inlet on 16 September 1977.

Following collection, anemones of all 3 species were relaxed in 50:50 seawater and isotonic $MgCl_2$. Specimens were cleaned, fixed in Hollande's fluid, and embedded in paraffin. Sections 8-10 μm thick, made through the basal half of the column of each specimen, were mounted, stained with picro-indigo carmine, counterstained with basic fuchsin, and examined and photographed through a compound microscope.

To assess female maturation in all 3 species, oogonia and oocytes from each identifiable female were measured from prepared sections by ocular micrometer. At least 50 gametogenic cells were measured from each female; generally only those cells which had a distinct nucleolus were measured, to standardize the diameter measurements, as well as to avoid counting the same oocyte twice. However, if fewer than 50 cells were present in the sections, all of them were measured, regardless of presence or absence of a nucleolus. Male maturity was determined by the presence or absence of gonial cells and tailed sperm (see Jennison, 1979). Additional serial sections were made of several specimens of *Actinia bermudensis* to study brooded planulae in detail.

Results—Of 82 specimens of *Actinia bermudensis* from the north jetty of Fort Pierce Inlet examined, 41 were females, 5 were males and 36 lacked

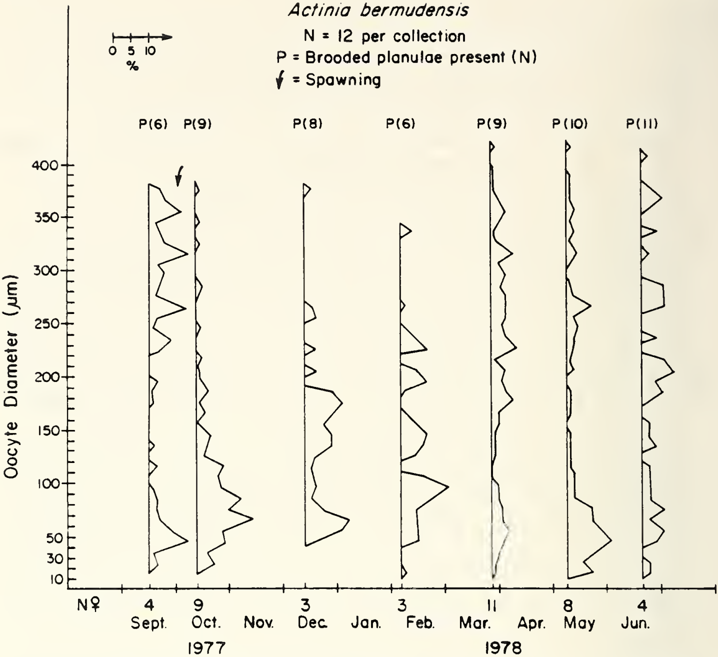


FIG. 1. Size-frequency histogram of oocyte dia of *Actinia bermudensis*. N = number of females in sample. P(6) = 6 adults brooding planulae in sample.

gonads. A broad range of oocyte sizes was present throughout the yr (Fig. 1). However, it is evident that the largest oocytes (300 µm dia and larger) began to be present in increasing numbers in the spring and summer. Abrupt spawning occurred between the September 16 and October 12 collections in 1977. Two of 5 males were found on 16 September 1977; 1 on 26 March 1978; and 2 on 21 June 1978. All had apparently ripe gonads, with bulging spermatogenic vesicles and clusters of tailed spermatozoa. No hermaphrodites were found, nor was there any evidence of asexual reproduction in this species.

Of 75 specimens of *Bunodosoma cavernata* from the south jetty of Jupiter Inlet, 19 were females, 29 were males, 26 lacked gonads, and 1 appeared to be an hermaphrodite. A chi-square test of females vs. males yielded an x^2 value of 1.69 ($0.5 < p < 0.1$), indicating the sex ratio varied significantly from one-to-one. Five ripe males were seen on 5 October 1977, and 4 spawned-out males containing torn spermatogenic vesicles and residual sperm were seen on 17 November 1977. Very early spermatogonial development was observed in 1 anemone on 20 January 1978; in 7 on 15 March 1978; and in 3 on 20 April 1978. By 24 May 1978, tailed sperm were observed in 4 anemones, indicating that the population was again becoming ripe (see Jennison, 1979 and 1981 for discussions of spermatogenesis in sea anemones). This apparently annual cycle paralleled the development of oocytes in females (Fig. 2). Ripe females were found in September and October 1977; spawning occurred between October and November, and no oocytes were observed during the winter. However, collections made on 15 March, 20 April and 24 May indicated that the females were again maturing (Fig. 2). One hermaphrodite was collected on 24 May 1978. This anemone contained vesicles of tailed sperm and small oocytes in the same mesentery. Further, several specimens of *Bunodosoma cavernata* exhibited vertical columnar scars which indicated that they had undergone asexual reproduction by longitudinal fission, as for example in *Anthopleura elegantissima* (Hand, 1955; Sebens, 1977, 1980).

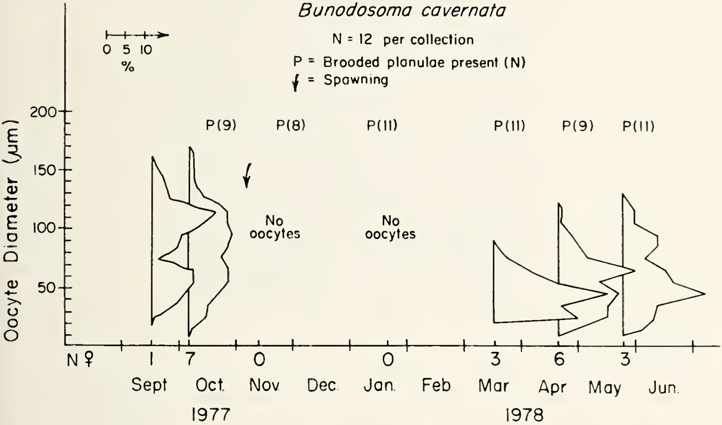


FIG. 2. Size-frequency histogram of oocyte dia of *Bunodosoma cavernata*. Legends as in Fig. 1.

Aiptasia pallida from Sebastian Inlet underwent asexual reproduction by pedal laceration in the field and in laboratory aquariums; it thus formed clones of genetically similar individuals. Ripe females were collected on 19 September 1977 (Fig. 3). These anemones contained oocytes up to 80 μm dia. By 27 October 1977 the population had spawned. Oocyte diameters remained small in the 13 December 1977 collection. By 8 February 1978, oocytes were growing larger. As no oocytes were observed in collections made on 27 March 1978, it is possible that the population had spawned again. However, large oocytes (50 μm and up) were observed in collections

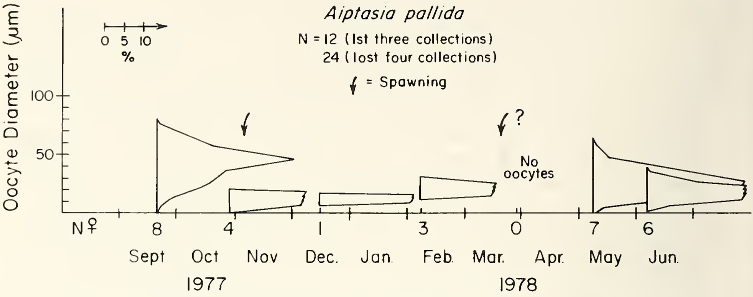


FIG. 3. Size-frequency histogram of oocyte dia of *Aiptasia pallida*. Legends as in Fig. 1.

made on 7 May and 6 June, so it is also possible that the lack of identifiable females in the 27 March sample was simply a collection artifact. Two males were found on 7 May in an adjacent clone.

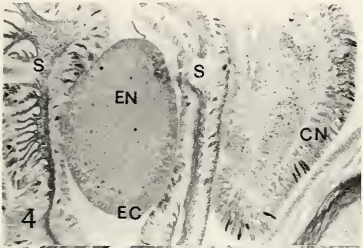
Actinia bermudensis brooded planular larvae throughout the year (Table 1). Planulae were present in 50% of the anemones collected on 16 September 1977 and in 60% or more of anemones in all subsequent collections. Of 41 females examined, 31 (76%) contained at least 1 larva. Four of the 5 males were brooding, as were 24 of the 36 anemones with no gonads (67%). As in *Actinia bermudensis*, *Bunodosoma cavernata* brooded planular larvae throughout the year. Planulae were present in 60% of the anemones collected on 5 October 1977, and in 82% to 92% of anemones in 4 collections made from 20 January to 24 May 1978. Of 19 females examined, 14 (74%) contained at least 1 larva. Of 29 males, 21 were brooding (72%), while 23 of 26 anemones with no gonads contained planulae (88%). The single hermaphrodite observed was also brooding. There was no evidence of brooding in *Aiptasia pallida*.

A study of serial sections of 2 specimens of *Actinia bermudensis* indicated that preserved planulae were ovoid to spherical, and up to 300 μm in dia (Fig. 4). A distinction could be made between larval ectoderm and endoderm, and the larvae appeared to contain a large amount of yolk. The larvae of *Bunodosoma cavernata* were quite similar to those of *Actinia bermudensis*, although somewhat smaller (Fig. 5). In neither species was there any tissue connection between the larvae and the host anemone, although the larvae were often closely associated with host septa (Figs. 4 & 5).

DISCUSSION—Identifications of anemones studied here were made according to Carlgren (1949, 1952). Although I am reasonably sure of the identities of *Aiptasia pallida* (Verrill, 1864) and *Bunodosoma cavernata* (Bosc, 1802), *Actinia bermudensis* McMurrich, 1889 may in fact be *Anemonia sargassensis* Hargitt, 1908 (R. Seaton, K. P. Sebens, pers. comm.).

Aiptasia pallida was found in isolated patches in the Indian River from

Sebastian to Jupiter. This species underwent asexual reproduction by pedal laceration; thus small groups of adjacent animals were undoubtedly descended from a single anemone. The preponderance of females in this study was most likely due to this phenomenon, as most specimens were collected from 1 large patch of anemones at Sebastian Inlet. When the sample was expanded to include anemones from a different patch, a few males were found. The 34 females found were among the largest anemones collected, while the 98 small anemones which lacked gonads were probably recent pedal lacerates.



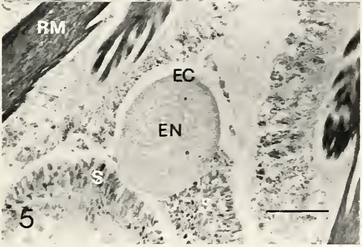


FIG. 4. (upper). Brooded planula of *Actinia bermudensis.* CN = parental cnidoglandular tract. EN = larval endoderm. EC = larval ectoderm. S = parental septa.

FIG. 5. (lower). Brooded planula of *Bunodosoma cavernata.* RM = parental retractor muscle. Other legends as in Fig. 4. Scale = 100 μm.

TABLE 1. *Actinia bermudensis* percent brooding.

	♀♀	♂♂	No Gonad	Total Brooding	Total Collected	% Brooding
Sept. 16, 1977	3	1	2	6	12	50%
Oct. 12	7	-	2	9	13	69%
Dec. 12	2	-	6	8	12	67%
Feb. 7, 1978	1	-	5	6	10	60%
Mar. 26	8	1	-	9	12	75%
May 8	7	-	3	10	12	83%
June 21	3	2	6	11	12	92%

TABLE 2. *Bunodosoma cavernata* percent brooding. *Indicates specimen collected at Ft. Pierce Inlet; all others collected at Jupiter Inlet.

	♀♀	♂♂	⚥⚥	No Gonad	Total Brooding	Total Collected	% Brooding
Sept. 16, 1977*	-	-	-	-	0	1	0%
Oct. 5	4	2	-	3	9	15	60%
Nov. 17	-	3	-	5	8	12	67%
Jan. 20, 1978	-	3	-	8	11	12	92%
Mar. 15	3	6	-	2	11	12	92%
April 20	5	1	-	3	9	11	82%
May 24	2	6	1	2	11	12	92%

Aiptasia pallida is a small anemone (individuals with pedal diameter of 0.25-0.5 mm comprised most of each collection); hence, the small oocyte sizes found (average dia approximately 50 μm) would be predicted (Chia, 1976). There is good evidence that *Aiptasia pallida* spawned in late September or early October 1977 (Fig. 3). While the lack of oocytes in the 27 March 1978 collection may have been a collection artifact rather than a spawning, it is germane to note that *Aiptasia pallida* females collected in the canal at Link Port on 20 April 1978 were spawning. Further, when oocytes from these anemones were mixed with sperm from the macerated gonads of males, fertilization was achieved (E. Ruppert, pers. comm.). Also, fertile specimens of this species were collected at Islamorada, Florida on 22 Mar 1975, as well as Grassy Key and Vaca Key on 26 September 1976 (R. Seaton, pers. comm.).

According to the oocyte size-frequency histogram (Fig. 2), *Bunodosoma cavernata* spawned in October 1977 at Jupiter Inlet. While oocyte dia data suggest the possibility of an annual spawning cycle, the presence throughout the yr of brooded planulae suggests that reproduction may occur at some level throughout the yr. Indeed, fertile specimens were found on the inlet jetty at Boca Raton on 18 March 1976 (R. Seaton, pers. comm.), and Lewis (1960) reported the release of larvae of 0.28 mm dia in June and July in Barbados.

Actinia bermudensis (or *Anemonia sargassensis)* clearly spawned between 16 September and 12 October 1977 at Fort Pierce Inlet (Fig. 1). This anemone produced relatively large oocytes, and brooded planulae were present throughout the yr. Specimens collected at Knights Key on 22 March 1977 also had "eggs" in their coelenterons (R. Seaton, pers. comm.). Indeed, initially I thought that I was finding free oocytes rather than planulae. However, Figures 4 and 5 clearly demonstrate the separation of thin ectoderm from yolky endoderm in both *Actinia bermudensis* and *Bunodosoma cavernata*, indicating that these are in fact brooded planulae. As no later stage juveniles were found in either species, presumably the planulae are released as such.

Brooding in sea anemones has received much attention recently. Loseva (1971) found *Tealia crassicornis* is viviparous in the Barents Sea, and

Spaulding (1971) described the embryonic and larval development of *Cribrinopsis williamsi*, which broods its planulae internally in Puget Sound. Dunn (1975) studied external brooding in *Epiactis prolifera* in California, and Rossi (1975) found brooding in *Cereus pedunculatus* in Europe. Siebert and Spaulding (1976) reported brooding in a second species of *Cribrinopsis*, *C. fernaldi*, in Puget Sound. Riemann-Zürneck (1976a, b) discussed "giant larvae" brooded by *Actinostola spetsbergensis* from Canada and the Arctic, and Dunn (1978) described brooding in *Anthopleura handi* from Malaysia. I reported the brooding of planulae and juveniles by *Phymanthus crucifer* in Key West (Jennison, 1981). Clearly brooding in sea anemones is widespread, and is not restricted to high or temperate latitudes.

Undoubtedly the preponderance of females in *Aiptasia pallida* was due to the sampling mainly of 1 clone, but why should the sex ratio be so skewed in *Actinia bermudensis*? The internal brooding anemones *Actinia equina* (see Carter and Thorp, 1979), *Actinia tenebrosa* (see Ottaway, 1979) and *Anthopleura handi* Dunn, 1978 all show a similar pattern. Dunn (1975) suggests that egg producers are at a premium in brooders; probably a relatively few males can spawn sufficient sperm to fertilize a large number of surrounding females.

A variety of theories has been advanced to account for the presence of brooded planulae in male sea anemones, or in anemones with no apparent gonads (Jennison, 1981). In short, the simplest explanation of this phenomenon is that of Ottaway (1979) and Dunn (1982), who suggest that adult anemones may undergo a sex change while brooding. If complete spawning and gonad resorption were a cyclic event, as has been shown in *Anthopleura elegantissima* (Jennison, 1979), and animals were reproductively plastic with respect to sex (or else were sequential hermaphrodites), then brooded planulae from a former female adult might well be found in that same animal following complete gonad resorption, or even as male gonads developed during the following breeding cycle. I believe that this theory is sufficient to explain the results reported here for *Actinia bermudensis* and *Bunodosoma cavernata*.

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Academy Symposium

ICHTHYOFAUNA OF THE NORTHERN PART OF THE INDIAN RIVER LAGOON SYSTEM, FLORIDA

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Abstract: *Between 1972 and 1980, about 1,800 fish collections were taken from the fresh and brackish waters of the Indian River lagoon system and adjacent Merritt Island in northern Brevard and southern Volusia counties, Florida. All habitat types were sampled and a variety of collecting gear was employed to insure a comprehensive survey of the regional fish fauna. The 139 species collected and 2 species reported in the literature are recorded in an annotated list. Eleven of the species collected had not previously been reported from the lagoon system. Comparison of this survey with that of Gilmore (1977a) reveals that the ichthyofauna in the northern part of the lagoon system is much less diverse than that in the southern part. There are about 337 fish species known from southern lagoon habitats and associated fresh waters and impoundments—more than twice the number of species collected in the northern region. The southern fauna includes more primary division freshwater fishes, more reef-associated species, and more species with oceanic and tropical affinities. Absence of many primary division freshwater fishes on Merritt Island is explained by lack of permanent fresh waters there prior to man's presence. Many freshwater species now inhabiting Merritt Island probably have been introduced by man. The reduced number of marine species in the north appears to be the result of the latitudinal temperature gradient, the absence of hard-bottom and reef-like habitats, and the limited number and wide separation of ocean inlets.*

Until recently, the ichthyofauna of the Indian River lagoon system on the central east coast of Florida (Fig. 1) was poorly known. Goode (1879) and Jordan (1880, 1884) listed several fish species from the lagoon system but gave imprecise locality data. Evermann and Bean (1897) summarized what was known about the fish fauna of the area, listing 106 species from the lagoons and adjacent fresh waters. However, their locality data were often vague; and many of their specimens were obtained from fish markets. In general, the emphasis of their report was on commercial species. It was not until the 1960s that additional reports on Indian River fishes were published. Both Springer (1960) and Gunter and Hall (1963) conducted surveys in the St. Lucie Inlet area, at the southern end of the estuary. Anderson and Gehringer (1965) listed some species, primarily of sport or commercial interest, from the Cape Canaveral area; but their report did not include specific locality data. During this period, some studies of limited taxonomic scope referenced Indian River fishes (e.g., Tabb, 1960, 1961; Harrington and Harrington, 1961; Dahlberg, 1970; Daly, 1970) but added little new information concerning the lagoonal ichthyofauna as a whole.

Recently, there has been renewed interest in the fish fauna of the Indian River system (Gilmore, 1974, 1977a, 1977b; Gilmore et al., 1976, 1978, 1981, 1983; Snelson, 1976, 1980a, 1981; Schooley, 1977, 1980; Snelson and Bradley, 1978; Hastings, 1978; Snelson and Williams, 1981; Gilmore and

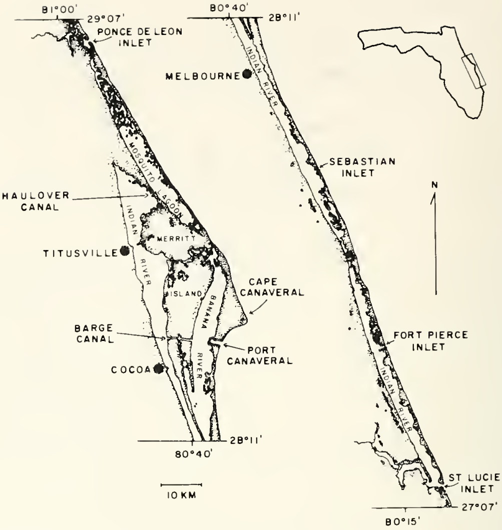

FIG. 1. The Indian River lagoon system, Florida.

Hastings, 1983; Mulligan and Snelson, 1982). The works of Gilmore (1977a) and Gilmore et al. (1981, 1983) are especially noteworthy, because they represent the first comprehensive summarization of the ichthyofauna of the region in over 80 yrs. However, these 3 reports were based on collections concentrated primarily in the near-shore ocean zone and in the southern half of the lagoon system, with relatively little attention devoted to the northern half (Gilmore, 1977a:Fig. 2; Gilmore et al., 1983). This study complements Gilmore's surveys by concentrating on the north-central section of the estuary. No systematic ichthyofaunal survey has been conducted in the Ponce de Leon Inlet-North Indian River Channel area at the extreme northern end of the lagoon system.

STUDY AREA AND METHODS—The Indian River lagoon system is mapped in Fig. 1. Environmental characteristics of the lagoons were described by Gilmore (1974, 1977a), Snelson (1976, 1980a), Gilmore et al. (1976), Snelson and Williams (1981), and Mulligan and Snelson (1982). This study is based on sampling conducted in the northern third of the system, between latitudes 28°25′ N and 28°52′ N, in the vicinity of Merritt Island in northern Brevard and extreme southern Volusia counties. Collections were made in Mosquito Lagoon, Indian River, and Banana River, and in tributaries and associated brackish and fresh waters of Merritt Island (Fig. 2).

About 1,800 fish collections were made in the study area between 1972 and 1980 (Fig. 2). Some collection sites were fixed sampling stations used for other studies (Snelson, 1976, 1980a, 1980b; Snelson and Wetherington, 1980; Mulligan and Snelson, 1982) and were sampled repeatedly, usually monthly. Other sites were collected only once.

Collecting was conducted year-round, but the greatest effort was concentrated during the summer and fall months. Collecting gear included seines, trawls, gill nets, cast nets, gigs, spears,

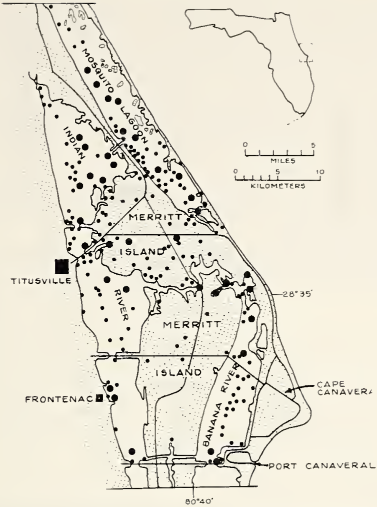

Fig. 2. The location of fish samples taken during the ichthyofaunal survey of the northern part of the Indian River lagoon system, Florida. Small dots represent sites sampled once; large dots represent sites sampled repeatedly, usually monthly.

dip nets, traps, and hook and line. In addition, specimens were taken during hypothermal fish kills (Snelson and Bradley, 1978) and from fishes impinged on the cooling-water intake screens at the Florida Power and Light Company (FP&L) generating station on the west shore of the Indian River at Frontenac. Most collecting was conducted during daylight, and no ichthyocides or narcotizing drugs were used.

Annotations in the species list are given in the following order. (1) Usual salinity regime(s): a. mesohaline — > 15 ppt; b. oligohaline — 1-14 ppt; c. fresh — < 1 ppt. (2) Typical habitat(s): a. open lagoon — depths > 0.5 m; b. lagoon perimeter — wave-washed zone < 0.5 m deep around shore and spoil islands; c. marshes — marshes, creeks, and bays with shallow water, silty substrate, and marginal mangroves or marsh grasses; d. ditches — man-made ditches and canals; e. impoundments — shallow, diked mosquito-control impoundments; f. ponds — man-made borrow ponds and flooded swales. (3) Relative abundance, slightly modified from Starck (1968): a. rare — 5 or fewer specimens seen or collected among a number of collections in appropriate habitat; b. occasional — collected or observed at irregular intervals; c. frequent — seen or collected on numerous occasions or taken in a large percentage of collections from appropriate habitat; d. common — found in varying numbers in virtually every collection from appropriate habitat; e. abundant — a common species present in large numbers. (4) Relevant literature and other comments as appropriate.

Scientific and common names follow Robins et al. (1980). Voucher samples of all species are housed in the fish collections of Florida State Museum and the University of Central Florida.

Annotated List of Fish Species

Family Carcharhinidae — requiem sharks

1. *Carcharhinus leucas* (bull shark).
   Mesohaline; open lagoon; frequent (Snelson and Williams, 1981).
2. *Carcharhinus limbatus* (blacktip shark).
   Mesohaline; open lagoon; abundance unknown but probably occasional and seasonal (Snelson and Williams, 1981).

3. *Carcharhinus plumbeus* (sandbar shark).
   Mesohaline; open lagoon; rare (Snelson and Williams, 1981).
4. *Negaprion brevirostris* (lemon shark).
   Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY SPHYRNIDAE—hammerhead sharks

5. *Sphyrna lewini* (scalloped hammerhead).
   Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY PRISTIDAE—sawfishes

6. *Pristis pectinata* (smalltooth sawfish).
   Once frequent in the lagoons but no recent records (Snelson and Williams, 1981).

FAMILY DASYATIDAE—stingrays

7. *Dasyatis americana* (southern stingray).
   Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).
8. *Dasyatis sabina* (Atlantic stingray).
   Mesohaline; open lagoon, lagoon perimeter; common (Snelson and Williams, 1981).
9. *Dasyatis sayi* (bluntnose stingray).
   Mesohaline; open lagoon, lagoon perimeter; common (Snelson and Williams, 1981).
10. *Gymnura micrura* (smooth butterfly ray).
    Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).

FAMILY MYLIOBATIDAE—eagle rays

11. *Aetobatus narinari* (spotted eagle ray).
    Mesohaline; open lagoon; occasional (Snelson and Williams, 1981).
12. *Rhinoptera bonasus* (cownose ray).
    Mesohaline; open lagoon; frequent but seasonal (Snelson and Williams, 1981).

FAMILY LEPISOSTEIDAE—gars

13. *Lepisosteus platyrhincus* (Florida gar).
    Fresh, oligohaline; ditches, ponds, impoundments; frequent.

FAMILY AMIIDAE—bowfins

14. *Amia calva* (bowfin).
    Fresh; ponds; occasional.

FAMILY ELOPIDAE—tarpons

15. *Elops saurus* (ladyfish).
    Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; frequent.
16. *Megalops atlanticus* (tarpon).
    Mesohaline, oligohaline; open lagoon, marshes, ditches, impoundments; occasional; larger individuals found in open lagoon areas, concentrating around heated power-plant effluent in winter; small individuals occasionally found in brackish ditches, creeks, and impoundments, although apparently not so commonly as further south (Gilmore, 1977a).

FAMILY ALBULIDAE—bonefishes

17. *Albula vulpes* (bonefish).
    Mesohaline; open lagoon; rare; 1 recently transformed individual seined in Banana River and 1 juvenile from FP&L site on Indian River; apparently more common further south in lagoon system (Gilmore et al., 1978).

FAMILY ANGUILLIDAE—freshwater eels

18. *Anguilla rostrata* (American eel).
    Mesohaline, possibly oligohaline; open lagoon, possibly ditches; abundance unknown but probably occasional; the sampling procedures employed were not ideal for collecting eels.

FAMILY OPHICHTHIDAE—snake eels

19. *Myrophis punctatus* (speckled worm eel).
    Mesohaline; open lagoon; abundance unknown but probably frequent; most captures at night, when relatively little sampling was conducted.

20. *Ophichthus gomesi* (shrimp eel).
Mesohaline; open lagoon; probably rare (Snelson, 1981).

FAMILY CLUPEIDAE — herrings

21. *Brevoortia smithi* (yellowfin menhaden).
Mesohaline; open lagoon; common.

22. *Brevoortia tyrannus* (Atlantic menhaden).
Mesohaline; open lagoon; frequent; notably less abundant than *B. smithi*; putative hybrids between the 2 menhaden species not uncommon (Dahlberg, 1970).

23. *Dorosoma cepedianum* (gizzard shad).
Mesohaline, oligohaline, fresh; open lagoon, ditches, impoundments; occasional; collected sporadically in wide variety of habitats; normally considered a freshwater species but found at salinities up to 37 ppt in Texas (Simmons, 1957).

24. *Harengula jaguana* (scaled sardine).
Mesohaline; open lagoon; abundant; prior to mid-1970s, this species was named *Harengula pensacolae* (Whitehead, 1973).

25. *Opisthonema oglinum* (Atlantic thread herring).
Mesohaline; open lagoon; common.

FAMILY ENGRAULIDAE — anchovies

26. *Anchoa cubana* (Cuban anchovy).
Mesohaline; open lagoon; occasional. The relative abundance of the 3 primary anchovy species in the study area is illustrated by trawl collections made in the summers of 1979 and 1980. The total catch of 93,244 anchovies was apportioned as follows: 92,558 (99.26%) *A. mitchilli*, 665 (0.71%) *A. hepsetus*, and 21 (0.02%) *A. cubana*.

27. *Anchoa hepsetus* (striped anchovy).
Mesohaline; open lagoon; frequent; widespread but never taken in large numbers.

28. *Anchoa mitchilli* (bay anchovy).
Mesohaline; open lagoon, lagoon perimeter; abundant; the most abundant marine fish in study area.

29. *Anchoa nasuta* (longnose anchovy).
Mesohaline; open lagoon; rare; a single specimen taken in April 1978 in Mosquito Lagoon.

FAMILY SYNODONTIDAE — lizard fishes

30. *Synodus foetens* (inshore lizardfish).
Mesohaline; open lagoon; occasional.

FAMILY CYPRINIDAE — minnows

31. *Notemigonus crysoleucas* (golden shiner).
Fresh; ponds, impoundments, ditches; frequent; taken only in permanent bodies of water.

FAMILY CATOSTOMIDAE — suckers

32. *Erimyzon sucetta* (lake chubsucker).
Fresh; ponds, impoundments, ditches; frequent; taken only in permanent bodies of water around dense vegetation.

FAMILY ICTALURIDAE — bullhead catfishes

33. *Ictalurus natalis* (yellow bullhead).
Fresh; ponds, impoundments, ditches; abundance unknown but probably occasional; because suitable sampling procedures were not frequently employed, collection records probably underrepresent abundance of this species on Merritt Island.

FAMILY ARIIDAE — sea catfishes

34. *Arius felis* (hardhead catfish).
Mesohaline; open lagoon; common.

35. *Bagre marinus* (gafftopsail catfish).
Mesohaline; open lagoon; frequent.

FAMILY BATRACHOIDIDAE — toadfishes

36. *Opsanus tau* (oyster toadfish).
Mesohaline; open lagoon, lagoon perimeter; frequent.

FAMILY GOBIESOCIDAE—clingfishes

37. *Gobiesox strumosus* (skilletfish).

Mesohaline; open lagoon; abundance unknown but probably frequent; because of its habit of clinging to and hiding under objects, my capture records, primarily with nets, probably underrepresent abundance of this species.

FAMILY OPHIDIIDAE—cusk-eels

38. *Ophidion marginatum* (striped cusk-eel).

Mesohaline; open lagoon; rare (Snelson, 1981).

FAMILY EXOCOETIDAE—flyingfishes

39. *Cypselurus melanurus* (Atlantic flyingfish).

Mesohaline; open lagoon; rare; a single individual found at FP&L plant on Indian River, July 1979; this species was referred to as *Cypselurus heterurus* prior to 1970 (Gibbs and Staiger, 1970).

40. *Hyporhamphus unifasciatus* (halfbeak).

Mesohaline; open lagoon; occasional; encountered infrequently but in large schools.

FAMILY BELONIDAE—needlefishes

41. *Strongylura marina* (Atlantic needlefish).

Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; occasional; not collected in freshwater habitats on Merritt Island (c.f., Herald and Strickland, 1949; McLane, 1955; Tagatz, 1968).

42. *Strongylura notata* (redfin needlefish).

Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common; the most abundant of the 3 needlefish species in study area (Snelson and Bradley, 1978).

43. *Strongylura timucu* (timucu).

Mesohaline; open lagoon, lagoon perimeter; rare; a single specimen collected October 1976 in Banana River near Port Canaveral; Schooley (1980) reported a single specimen from Mosquito Lagoon. Because of the nature of the diagnostic characters (Collette, 1968), it is difficult to distinguish *S. timucu* and *S. marina* specimens less than 30 mm standard length. Nevertheless, careful evaluation of all large specimens available demonstrates that *S. timucu* is quite rare.

FAMILY CYPRINODONTIDAE—killifishes

44. *Cyprinodon variegatus* (sheepshead minnow).

Oligohaline, mesohaline; impoundments, ditches, marshes, occasionally lagoon perimeter; abundant; characteristic of protected areas with sand-silt sediments; distribution complementary to that of next species.

45. *Floridichthys carpio* (goldspotted killifish).

Mesohaline, occasionally oligohaline; lagoon perimeter, marshes; abundant; unlike preceding species, this one never found in either impoundments or ditches on Merritt Island; characteristic of exposed, wave-washed shore zones, where bottom sediments sand-shell and vegetation sparse; occasionally trawled in open lagoon in areas with abundant drift algae.

46. *Fundulus chrysotus* (golden topminnow).

Fresh; ditches, impoundments, ponds; frequent; typical of areas with dense submerged and emergent vegetation; widely distributed on Merritt Island, but nowhere abundant.

47. *Fundulus confluentus* (marsh killifish).

Oligohaline, occasionally mesohaline; impoundments, ditches, marshes; frequent; although rarely seined, often collected in numbers in baited minnow traps; an inhabitant of freshwater environments on mainland (Relyea, 1975) but never collected in freshwater on Merritt Island.

48. *Fundulus grandis* (gulf killifish).

Mesohaline, oligohaline; impoundments, ditches, marshes, lagoon perimeter; common.

49. *Fundulus heteroclitus* (mummichog).

Only record from Indian River region is report by Relyea (1975) from near Edgewater, north of my study area; the locality is in Volusia County, not Brevard County as stated by Relyea.

50. *Fundulus seminolis* (Seminole killifish).

Fresh, oligohaline; impoundments, ponds, ditches, marshes; occasional; although usually a freshwater species on mainland (Relyea, 1975; DuRant et al., 1979), collected sporadically over wide salinity range (0-25 ppt) in and around Merritt Island.

51. *Fundulus similis* (longnose killifish).

Mesohaline; lagoon perimeter; occasional.

52. *Jordanella floridae* (flagfish).

Fresh; ditches, ponds, impoundments; frequent; always found in small numbers; characteristic of areas with dense submerged and emergent vegetation.

53. *Lucania goodei* (bluefin killifish).

Fresh; ponds, ditches, impoundments; common; the few individuals collected in brackish waters appeared to be wafted from adjacent freshwater areas during periods of high water; characteristic of habitats with abundant submerged and emergent vegetation.

54. *Lucania parva* (rainwater killifish).

Oligohaline, mesohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common to abundant; habitat and abundance pattern contrasts sharply with preceding species; most abundant in shallow brackish waters where vegetation sparse or nonexistent; in open lagoons, closely associated with beds of drift algae and seagrasses; although common in essentially fresh waters of St. Johns River basin (Tagatz, 1968), collected infrequently and in low abundance in fresh waters on Merritt Island.

FAMILY POECILIIDAE — livebearers

55. *Gambusia affinis* (mosquitofish).

Fresh, oligohaline, mesohaline; virtually ubiquitous except for the open lagoon waters; abundant.

56. *Heterandria formosa* (least killifish).

Fresh; ponds, impoundments, ditches; frequent; collected regularly but in low abundance in habitats where submerged aquatic vegetation was dense.

57. *Poecilia latipinna* (sailfin molly).

Mesohaline, oligohaline, fresh; lagoon perimeter, ditches, impoundments, marshes; abundant; rare in open lagoon areas and encountered regularly but in low numbers in strictly freshwater; everywhere abundant in protected mesohaline and oligohaline waters, especially where submerged vegetation dense.

FAMILY ATHERINIDAE — silversides

58. *Membras martinica* (rough silverside).

Mesohaline; lagoon perimeter; occasional; collected only twice, once around spoil island in northern Indian River and once in Haulover Canal; additional night collecting may prove this species to be more common than my records indicate.

59. *Menidia beryllina* (inland silverside).

Oligohaline, fresh; ditches, impoundments; occasional.

60. *Menidia peninsulae* (tidewater silverside).

Mesohaline, oligohaline; lagoon perimeter, marshes, ditches, impoundments; abundant. Silverside populations associated directly with the lagoon system appear to be *M. peninsulae*. Populations from some low salinity ditches and impoundments on Merritt Island are tentatively identified as *M. beryllina*. However, some populations from brackishwater habitats on Merritt Island are not clearly assignable to either species on the basis of diagnostic morphological characters emphasized by Johnson (1975) and Chernoff et al. (1981), suggesting the possibility of hybridization.

FAMILY SYNGNATHIDAE — pipefishes

61. *Hippocampus erectus* (lined seahorse).

Mesohaline; open lagoon, lagoon perimeter; occasional; much less common than following species.

62. *Hippocampus zosterae* (dwarf seahorse).

Mesohaline; open lagoon, lagoon perimeter; frequent; typically found in shallow seagrass beds.

63. *Syngnathus louisianae* (chain pipefish).

Mesohaline; open lagoon; occasional; characteristic of deeper areas; usually collected by trawling in areas where little or no vegetative cover was present.

64. *Syngnathus scovelli* (gulf pipefish).
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; common to abundant in seagrass beds and drifting macroalgae (Kulczycki et al., 1981; Mulligan and Snelson, 1982); not collected in fresh water on Merritt Island.

FAMILY CENTROPOMIDAE—snooks

65. *Centropomus undecimalis* (snook).
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; frequent; adults characteristic of deeper water, especially in dredged areas and around bridges, navigation markers, and other protective cover; juveniles usually in oligohaline creeks; suffered considerable stress and mortality during unusually cold winter of 1977 (Snelson and Bradley, 1977; Gilmore et al., 1978).

FAMILY SERRANIDAE—sea basses

66. *Cetropristis philadelphica* (rock sea bass).
Mesohaline; open lagoon; rare; only 2 specimens known from study area, 1 trawled near northern end of Indian River, 1 collected at FP&L site on Indian River.

67. *Mycteroperca microlepis* (gag).
Mesohaline; open lagoon; occasional; 6 records, all from Mosquito Lagoon.

FAMILY CENTRARCHIDAE—sunfishes

68. *Lepomis gulosus* (warmouth).
Fresh; ditches, ponds, impoundments; frequent; a secretive species typically collected in close association with vegetation, overhanging brush, and other types of protective cover.

69. *Lepomis macrochirus* (bluegill).
Fresh; ponds, ditches, impoundments; common; typically found in larger, more-permanent bodies of water.

70. *Lepomis marginatus* (dollar sunfish).
Fresh; ponds, ditches, impoundments; occasional; a small, secretive species inhabiting shallow, weedy, littoral areas; collected at scattered localities throughout Merritt Island.

71. *Lepomis microlophus* (redear sunfish).
Fresh; ponds, ditches, impoundments; frequent; co-occurred with *L. macrochirus* throughout Merritt Island but usually less abundant.

72. *Lepomis punctatus* (spotted sunfish).
Fresh; ditches; rare; collected at a single site on Merritt Island, a roadside ditch 0.5 km E. jct. Hwys. 402 and 3; 10 specimens were taken in 31 collections at this site between November 1972 and May 1975.

73. *Micropterus salmoides* (largemouth bass).
Fresh, occasionally oligohaline; ditches, ponds, impoundments; frequent; typically found in larger, deeper, more-permanent bodies of water.

74. *Pomoxis nigromaculatus* (black crappie).
Fresh; impoundments; only 1 individual captured, but fishermen claim there are good populations in 2 freshwater impoundments.

FAMILY POMATOMIDAE—bluefishes

75. *Pomatomus saltatrix* (bluefish).
Mesohaline; open lagoon; occasional; records sporadic but from all seasons, indicating this species is a year-round inhabitant.

FAMILY ECHENEIDAE—remoras

76. *Echeneis naucrates* (sharksucker).
Mesohaline; open lagoon; rare (Snelson and Bradley, 1978; Snelson, 1981).

77. *Echeneis neucratoides* (whitefin sharksucker).
Mesohaline; open lagoon; rare (Snelson, 1981).

FAMILY CARANGIDAE—jacks

78. *Caranx crysos* (blue runner).
Mesohaline; open lagoon; rare (Snelson and Bradley, 1978).

79. *Caranx hippos* (crevalle jack).
Mesohaline; open lagoon; common.

80. *Caranx latus* (horse-eye jack).
Mesohaline; open lagoon; occasional; appears to travel in schools with preceding species, but always much less abundant.

81. *Chloroscombrus chrysurus* (Atlantic bumper).
Mesohaline; open lagoon; occasional.

82. *Oligoplites saurus* (leatherjacket).
Mesohaline; open lagoon, lagoon perimeter; frequent; young often float motionless just below surface, mimicking drifting pieces of seagrass or algae.

83. *Selene setapinnis* (Atlantic moonfish).
Mesohaline; open lagoon; rare; 1 specimen collected by gill net in Mosquito Lagoon and 1 trawled in northern end of Indian River; until recently, this species went under the genus name *Vomer* (Berry and Smith-Vaniz, 1978).

84. *Selene vomer* (lookdown).
Mesohaline; open lagoon; occasional; in addition to specimen reported by Snelson and Bradley (1978), 2 juveniles trawled in Banana River near Port Canaveral, 2 adults recovered from FP&L station on Indian River, and 2 juveniles trawled in northern part of Mosquito Lagoon.

85. *Trachinotus carolinus* (Florida pompano).
Mesohaline; open lagoon; occasional; collected sporadically throughout study region; experienced gill-net fishermen occasionally take commercially significant quantities, especially during late summer and fall (Anderson and Gehringer, 1965; Snelson, 1980a).

86. *Trachinotus falcatus* (permit).
Mesohaline; open lagoon; occasional; less abundant than preceding species but occasionally taken in numbers by gill-net fishermen (Snelson and Bradley, 1978; Snelson, 1980a).

FAMILY LUTJANIDAE—snappers

87. *Lutjanus griseus* (gray snapper).
Mesohaline; open lagoon, lagoon perimeter; frequent; usually found around cover such as pilings, bridges, and riprap; occasionally taken in commercial quantities by gill-net fishermen in Mosquito Lagoon (Snelson, 1980a). Schooley (1980) reported a single specimen of another lutjanid species, *Lutjanus synagris*, from Mosquito Lagoon; but the specimen is not available for confirmation.

FAMILY LOBOTIDAE—tripletails

88. *Lobotes surinamensis* (tripletail).
Mesohaline; open lagoon; rare; 5 specimens, all taken in August and September 1979 from intake screens at FP&L power plant on Indian River.

FAMILY GERREIDAE—mojarras

89. *Diapterus auratus* (Irish pompano).
Mesohaline; open lagoon; frequent; young and juveniles encountered more often than adults; usually found over soft sand-silt bottoms; until recently, this species was named *Diapterus olisthostomus* (Miller, 1976).

90. *Diapterus plumieri* (striped mojarra).
Mesohaline; open lagoon; rare; only 2 specimens known from study region, 1 from Banana River (Snelson and Bradley, 1978), 1 from Indian River at Frontenac.

91. *Eucinostomus argenteus* (spotfin mojarra).
Mesohaline; open lagoon, lagoon perimeter; common; this and following species usually collected together, seem to show little habitat segregation; usually found over soft silt or sand-silt bottoms.

92. *Eucinostomus gula* (silver jenny).
Mesohaline; open lagoon, lagoon perimeter; common. Schooley (1977) reported *E. lefroyi* from Banana River but specimens are not available for confirmation.

FAMILY HAEMULIDAE—grunts

93. *Orthopristis chrysoptera* (pigfish).
Mesohaline; open lagoon; frequent; usually associated with seagrass beds; often caught in traps and sold as preferred bait for hook and line fishing for large spotted seatrout (Tabb, 1960; pers. observ.). Schooley (1980) reported another haemulid species, *Haemulon sciurus*, from Mosquito Lagoon; but the specimens are not available for confirmation.

FAMILY SPARIDAE—porgies

94. *Archosargus probatocephalus* (sheepshead).

Mesohaline; open lagoon; common; usually found around structures such as piers, navigation markers, and bridges.

95. *Lagodon rhomboides* (pinfish).

Mesohaline; open lagoon, lagoon perimeter; common to abundant; usually associated with seagrass beds.

FAMILY SCIAENIDAE—drums

96. *Bairdiella chrysoura* (silver perch).

Mesohaline; open lagoon; abundant.

97. *Cynoscion nebulosus* (spotted seatrout).

Mesohaline; open lagoon; common; a highly prized sport and commercial species; by dollar value, the most important commercial fin-fish in lagoon system (Anderson and Gehringer, 1965); Indian River system populations grow faster than any other Florida population examined by Tabb (1961).

98. *Cynoscion regalis* (weakfish).

Mesohaline; open lagoon; frequent; only young and juveniles taken, most by trawling.

99. *Leiostomus xanthurus* (spot).

Mesohaline; open lagoon; common to abundant; usually trawled over unvegetated sand or sand-silt bottoms; a significant commercial species in lagoon system (Anderson and Gehringer, 1965; Snelson, 1980a).

100. *Menticirrhus americanus* (southern kingfish).

Mesohaline; open lagoon; frequent; adults most common in winter and early spring months. Schooley (1977) reported a single individual of *M. saxatilis* from the Indian River near Titusville, but the specimen is not available for confirmation.

101. *Micropogonias undulatus* (Atlantic croaker).

Mesohaline; open lagoon; frequent; a valuable food fish but not taken in significant commercial quantities in study area (Snelson, 1980a); until recently, treated under generic name *Micropogon* (Chao, 1978).

102. *Pogonias cromis* (black drum).

Mesohaline; open lagoon, lagoon perimeter, marshes; frequent; large adults up to 28 kg taken in gill nets in open lagoon; young usually taken in mangrove-lined shore zones.

103. *Sciaenops ocellata* (red drum).

Mesohaline; open lagoon, lagoon perimeter, marshes; frequent to common; young and juveniles usually taken in shallow shore zones; large adults up to 16 kg taken in gill nets in deeper water; an important sport and food fish.

FAMILY EPHIPPIDAE—spadefishes

104. *Chaetodipterus faber* (Atlantic spadefish).

Mesohaline; open lagoon; frequent to common around docks, bridges, and navigation markers.

FAMILY SCARIDAE—parrotfishes

105. *Nicholsina usta* (emerald parrotfish).

Mesohaline; open lagoon; rare; only 3 individuals taken, all impinged on water intake screens at FP&L power plant, summer 1979.

FAMILY MUGILIDAE—mullets

106. *Mugil cephalus* (striped mullet).

Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common to abundant; based on annual landings, the most important commercial fish species in lagoon system, with greatest landings between July and October (Anderson and Gehringer, 1965; Snelson, 1980a).

107. *Mugil curema* (white mullet).

Mesohaline; open lagoon, lagoon perimeter, marshes; common to abundant; unlike situation further south in lagoon system (Gilmore, 1977a), not found in impounded brackish waters on Merritt Island; smaller than preceding species, of limited commercial value.

FAMILY SPHYRAENIDAE—barracudas

108. *Sphyraena barracuda* (great barracuda).

Mesohaline; open lagoon; rare; 1 young seined near Port Canaveral locks in

Banana River, 1 juvenile caught by sport fisherman in Banana River.

109. *Sphyraena borealis* (northern sennet).
Mesohaline; open lagoon; rare; single specimen from FP&L power plant on Indian River.

FAMILY URANOSCOPIDAE—stargazers

110. *Astroscopus y-graecum* (southern stargazer).
Mesohaline; open lagoon; rare; 1 specimen from Mosquito Lagoon, 1 from Indian River.

FAMILY BLENNIIDAE—combtooth blennies

111. *Chasmodes saburrae* (Florida blenny).
Mesohaline; open lagoon, lagoon perimeter; common; typically taken in seagrass beds, shell beds, riprap, and other types of protective cover.

112. *Hypleurochilus geminatus* (crested blenny).
Mesohaline; open lagoon; rare (Snelson, 1981).

FAMILY ELEOTRIDAE—sleepers

113. *Dormitator maculatus* (fat sleeper).
Oligohaline, fresh; marshes, ditches; occasional; usually found in small ditches or canals draining directly into lagoon.

FAMILY GOBIIDAE—gobies

114. *Bathygobius soporator* (frillfin goby).
Mesohaline; lagoon perimeter; rare; a single specimen collected in northern end of Banana River; there is very little suitable habitat for this species in study area.

115. *Evorthodus lyricus* (lyre goby).
Mesohaline; lagoon perimeter, marshes; rare; small sample taken on 2 separate occasions at same site near Port Canaveral locks in Banana River; not found in other areas where habitat seemed to be suitable.

116. *Gobioides broussoneti* (violet goby).
Mesohaline; open lagoon; rare; 2 specimens taken at FP&L site on Indian River.

117. *Gobionellus boleosoma* (darter goby).
Mesohaline; open lagoon, lagoon perimeter; occasional; collected irregularly in small numbers in Banana River and Indian River; much more common north (Ponce de Leon Inlet) and south (Sebastian Inlet) of study area.

118. *Gobionellus oceanicus* (highfin goby).
Mesohaline; open lagoon; occasional; found throughout study area but always uncommon; some evidence suggests that it is most active at night. Both *G. oceanicus* and *G. hastatus* have been reported from the lagoon system (Gilmore, 1977a; Snelson, 1980a), but recent studies by Mr. Frank Pezold (pers. comm.) indicate that only one variable species is present.

119. *Gobionellus smaragdus* (emerald goby).
Mesohaline; open lagoon; rare; 2 individuals taken in Banana River near the Port Canaveral locks.

120. *Gobiosoma bosci* (naked goby).
Oligohaline; marshes, ditches, impoundments; frequent; characteristic of low-salinity habitats.

121. *Gobiosoma robustum* (code goby).
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes; abundant; strongly associated with the drift macroalgae community (Kulczycki et al., 1981; Mulligan and Snelson, 1982), but found in a diversity of habitats; characteristically inhabits higher salinities than preceding species, although they were taken together at one brackish ditch on several occasions.

122. *Microgobius gulosus* (clown goby).
Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches, impoundments; common; usually collected over soft sand or silt substrates; not collected in strictly fresh water on Merritt Island.

123. *Microgobius thalassinus* (green goby).
Mesohaline; open lagoon; occasional; collected most often in trawl over bare sand-silt bottoms; found irregularly throughout study area but always in small numbers.

FAMILY TRICHIURIDAE—cutlassfishes

124. *Trichiurus lepturus* (Atlantic cutlassfish).

Mesohaline; open lagoon; occasional; seasonally common in Port Canaveral and around inlets, but sporadic in northern part of lagoon system.

FAMILY SCOMBRIDAE—mackerels

125. *Scomberomorus maculatus* (Spanish mackerel).

Mesohaline; open lagoon; occasional; a few specimens from Mosquito Lagoon and Banana River (Snelson and Bradley, 1978); infrequently caught by commercial fishermen in Banana River.

FAMILY SCORPAENIDAE—scorpionfishes

126. *Scorpaena brasiliensis* (barbfish).

Mesohaline; open lagoon; rare; 4 specimens, all taken at FP&L power plant on Indian River.

FAMILY TRIGLIDAE—searobins

127. *Prionotus scitulus* (leopard searobin).

Mesohaline; open lagoon; occasional; records from Mosquito Lagoon and Indian River.

128. *Prionotus tribulus* (bighead searobin).

Mesohaline; open lagoon; frequent.

FAMILY BOTHIDAE—lefteye flounders

129. *Citharichthys spilopterus* (bay whiff).

Mesohaline; open lagoon; occasional; scattered records from Mosquito Lagoon and Indian River.

130. *Etropus crossotus* (fringed flounder).

Mesohaline; open lagoon; rare; a single specimen taken June 1979 at FP&L power plant on Indian River.

131. *Paralichthys albigutta* (gulf flounder).

Mesohaline; open lagoon; frequent.

132. *Paralichthys lethostigma* (southern flounder).

Mesohaline; open lagoon; occasional; encountered only about half as often as preceding species.

FAMILY SOLEIDAE—soles

133. *Achirus lineatus* (lined sole).

Mesohaline, oligohaline; open lagoon, lagoon perimeter, marshes, ditches; common.

134. *Trinectes maculatus* (hogchoker).

Oligohaline; lagoon perimeter, marshes, ditches, impoundments; frequent; occurs at lower salinities than preceding species but not collected in fresh water on Merritt Island.

FAMILY CYNOGLOSSIDAE—tonguefishes

135. *Symphurus plagiusa* (blackcheek tonguefish).

Mesohaline; open lagoon; occasional.

FAMILY BALISTIDAE—leatherjackets

136. *Aluterus schoepfi* (orange filefish).

Mesohaline; open lagoon; rare; 2 specimens from Indian River, 1 near Titusville, 1 at Frontenac.

137. *Monacanthus hispidus* (planehead filefish).

Mesohaline; open lagoon; common around bridges, piers, navigation markers, and similar structures.

FAMILY TETRAODONTIDAE—puffers

138. *Sphoeroides nephelus* (southern puffer).

Mesohaline; open lagoon, lagoon perimeter; common; strongly associated with seagrass beds.

139. *Sphoeroides spengleri* (bandtail puffer).

Mesohaline; open lagoon, lagoon perimeter; occasional; 1 specimen from Banana River (Snelson and Bradley, 1978) and several from Indian River between Frontenac and Titusville.

140. *Sphoeroides testudineus* (checkered puffer).
Mesohaline; open lagoon; rare; 1 specimen from FP&L site on Indian River.

FAMILY DIODONTIDAE—porcupinefishes

141. *Chilomycterus schoepfi* (striped burrfish).
Mesohaline; open lagoon, lagoon perimeter; common; the related *Diodon hystrix* was reported from Cocoa by Evermann and Bean (1897) but has not been collected anywhere in lagoon system in recent years (Gilmore, 1977a).

DISCUSSION—The combined species lists of Gilmore (1977a) and Gilmore et al. (1983), incorporating additions, deletions, and corrections published elsewhere (Gilmore et al., 1978, 1981; Hastings, 1978; Snelson and Bradley, 1978; Snelson, 1981; Snelson and Williams, 1981), include 337 fish species known from the entire Indian River lagoon system (exclusive of inlets) and associated fresh waters. The 141 species reported in this study represent only a fraction of the species known from the entire system. Although a few species have been recorded from the northern part of the lagoon system that have not been reported in the southern part, nearly 200 species reported from the southern section have not been discovered in my study area. Some of the southern species that are missing from the Merritt Island area probably occur in the Ponce de Leon Inlet area at the extreme northern end of the estuary. Unfortunately, the fish fauna in that area has not been surveyed. In addition, Gilmore's lists (Gilmore, 1977a; Gilmore et al., 1981, 1983) are slightly inflated because they include some hybrids and exotic species and a few species of questionable status or identification. Furthermore, the sampling gear and protocol employed in my and Gilmore's surveys were not identical. Despite these qualifications, it is clear that the northern part of the lagoon system is strikingly depauparate when compared with the southern part. The remainder of the Discussion will be devoted to considerations of this difference.

Freshwater Fishes: The compiled species list of Gilmore et al. (1981) includes 33 native freshwater species, i.e., primary division freshwater species plus secondary division freshwater species that are found almost exclusively in freshwater habitats (Myers, 1938). Only 16 of these species were collected during this study. However, a detailed comparison of the freshwater fish faunas in the southern and north-central parts of the lagoon system is not appropriate because there is so little "natural" fresh water in the north. In the south, the St. Lucie River system, the Sebastian Creek system, several major freshwater drainage canal systems, and several smaller drainages flow into the Indian River from the west (Gilmore, 1977a; Gilmore and Hastings, 1983). In contrast, other than the highly disturbed Sykes Creek on southern Merritt Island, no major freshwater tributaries exist within my study area. Freshwater habitats on Merritt Island are either ephemeral swales, which contain water only during the wet season, or borrow ponds, impoundments, and ditches that have resulted from man's recent activities. Clearly, little or no permanent fresh water existed on Merritt Island prior to human occupation. Furthermore, the relatively recent formation and dynamic nature of the Cape Canaveral and Merritt Island land masses (White, 1958, 1970), combined with late Pleistocene interglacial sea levels at least 8-9 m higher than the current level (Cook, 1945; Alt and Brooks, 1965), suggest that the Merritt Island-Cape Canaveral area has not provided stable habitats for freshwater fishes for a substantial period of geological time.

Most freshwater fishes listed by Gilmore et al. (1981) that are missing from the Merritt Island study area probably will be discovered in the Ponce de Leon Inlet area at the extreme northern end of the lagoon system (Fig. 1). The Spruce Creek drainage system is tributary to the lagoon in that area and is large enough to provide diverse freshwater habitats. Three of the missing species, *Leptolucania ommata*, *Elassoma evergladei*, and *Etheostoma fusiforme*, were recorded from "Indian River near Titusville" by Jordan (1884). Because these species are normally found in fresh water, they probably were not taken in the Indian River itself but in a tributary or an isolated body of fresh water. I was unable to find these species or appropriate habitat in the immediate vicinity of the Indian River near Titusville. Because some of the other species Jordan listed from "Indian River near Titusville" are typical of brackish water, e.g., *Fundulus similis*, *F. heteroclitus* (probably *F. grandis*), *Mugil* sp., and *Microgobius gulosus*, I believe that fishes from at least 2 separate localities were pooled.

Consideration of the freshwater fishes that do and do not occur on Merritt Island suggests that many of the species there have been introduced. Centrarchid species valued as game or pan fish (*Lepomis* sp., *Micropterus salmoides*, *Pomoxis nigromaculatus*) are well represented on Merritt Island, yet small centrarchids (*Elassoma evergladei*, *Enneacanthus* sp.) are not present. Centrarchids are primary division freshwater fishes (Myers, 1938), not able to cross salinity barriers. Thus, selected species probably have been intentionally introduced on Merritt Island. Although details are vague, *Ictalurus* sp., *Lepomis* sp., and *Micropterus salmoides* were stocked in freshwater habitats on Merritt Island in the early and mid-1960s and early 1970s (Messrs. R. C. Lee, Jr., J. Salmela, and E. A. Zagar, pers. comm.). "Unofficial" stockings prior to 1960 are reasonably inferred. Other primary division freshwater species present on Merritt Island (*Notemigonus crysoleucas* and *Erimyzon sucetta*) are popular bait used by largemouth bass anglers. These species may be present as a result of bait-bucket releases or intentional stockings, because related but non-bait species (*Notropis emiliae*, *N. maculatus*) that are common in appropriate freshwater habitats on the adjacent mainland are not present on Merritt Island.

Other expected species that are absent from Merritt Island include *Esox americanus*, *Ictalurus nebulosus*, *Noturus gyrinus*, *Fundulus lineolatus*, *Fundulus cingulatus*, *Leptolucania ommata*, and *Etheostoma fusiforme*. All are present in appropriate freshwater habitats on the adjacent mainland (McLane, 1955; Tagatz, 1968; pers. observ.) and in freshwater tributaries to the lagoon in the south (Gilmore, 1977a; Gilmore et al., 1983). All are primary division freshwater species (Myers, 1938) and are not likely to cross the saline lagoon to establish themselves on the Island. Most freshwater species inhabiting Merritt Island that were not intentionally or unintentionally introduced by man probably have invaded from the mainland relatively recently across low-salinity barriers.

Marine Fishes: Considering all brackish-water habitats except ocean inlets, there are about 155 fish species in recent collections from the southern part of the lagoon system that were not found in the Merritt Island study area. In contrast, only 10 brackish-water species reported from the northern part of the lagoon are not also reported in the south (Gilmore, 1977a; Gilmore et al., 1978, 1981, 1983; Hastings, 1978; Gilmore and Hastings, 1983). In addition to differences in species diversity, comparison of Gilmore (1977a) and Gilmore et al. (1981) with this report suggests that there are also dramatic north-south differences in the relative abundance of many species, for example *Anchoa cubana*, *Fundulus similis*, *Sphyraena barracuda*, and *Scorpaena brasiliensis*. However, it is impossible to make rigorous comparisons on the basis of qualitative statements of abundance; and I will not elaborate on possible north-south abundance trends.

The ichthyofaunal list for the southern part of the estuary is based on collections made primarily between latitudes 27°10′ N and 28°25′ N, a distance of about 139 km (Gilmore, 1977a). The species list reported herein is based on collections made between latitudes 28°25′ N and 28°52′ N, a distance of about 50 km. However, the possibility that the difference in species diversity between the 2 areas might be simply a species number-area effect (Connor and McCoy, 1979) can be easily discounted. In the south, the system consists of only a single narrow body of water, the Indian River. In the north, the system consists of three separate divisions, i.e., Indian River, Banana River, and Mosquito Lagoon, each at least 1.5 times as wide as the southern part of the Indian River (Fig. 1). In fact, the lagoon surface area in my study region is probably about the same as in the region emphasized by Gilmore (1977a).

Three interacting factors, namely (1) latitude and climate, (2) habitat diversity, and (3) ocean access, seem to be primarily responsible for the greater fish species diversity in the southern part of the lagoon system.

(1) Cape Canaveral marks the approximate center of a broad transition zone between the warm-temperate Carolinian and tropical Caribbean faunal regions (Briggs, 1974; Gilmore, 1977a). One of the major north-south differences in the lagoon fish fauna is the much stronger representation of tropical families in the south (e.g., Serranidae, Apogonidae, Lutjanidae, Haemulidae, Chaetodontidae, Pomacentridae, Labridae, Scaridae, Gobiidae). Tropical species progressively disappear from the estuarine fauna from south to north. From Cape Canaveral northward, most distinctly tropical species either do not occur or else are found only along the coast or in the deep, thermally stable waters offshore, often only during the summer season (Gilbert, 1969, 1973). Tropical species are among the most seriously affected in periods of unusually cold weather (Snelson and Bradley, 1978; Gilmore et al., 1978). Clearly, the north-south cline in average lagoon water

temperature (Gilmore, 1974) is an important factor controlling the northern distributional limit of many tropical species.

Tropical fishes found in the southern part of the lagoon system but not known from the Cape Canaveral area are too numerous to list. Exemplary species are *Gobionellus pseudofasciatus* and *Gobiomorus dormitator* (Gilmore and Hastings, 1983), *Rivulus marmoratus* and *Centropomus parallelus* (Gilmore et al., 1983), and *Hypoplectus unicolor* and *Halichoeres bivittatus* (Gilmore, 1977a). Several species, for example *Floridichthys carpio* (Relyea, 1975), *Chasmodes saburrae* (Williams, 1979), *Strongylura notata*, *S. timucu*, and *Hippocampus zosterae*, reach their northern distributional limit on the Florida east coast at the northern end of the Indian River system; and the ranges of many other southern species terminate in the zone between Daytona Beach and the Florida-Georgia border. In contrast, only 1 temperate species (*Fundulus heteroclitus*) reaches its southern distributional limit in the northern part of the lagoon system (Relyea, 1975). Most species typical of the Carolinian fauna extend southward throughout the estuary.

(2) The virtual absence of hard-bottom and reef-like habitats in the northern part of the lagoon system explains the absence of many fish species. Of the 155 marine species recorded in the south but not discovered in my survey, about 30% are typically associated with reefs or reef-like habitats, at least as adults. Examples are *Holacanthus bermudensis*, *Pomacentrus partitus*, *Apogon maculatus*, and *Malacoctenus macropus* (Gilmore, 1977a). Reef-like habitats are prevalent in the southern part of the estuary, especially south of Sebastian Inlet. Gilmore (1977a) described undercut coquina rock ledges along the edge of the Intracoastal Waterway in northern St. Lucie County that supported numerous invertebrate and fish species normally associated with true ocean reefs. The only place in my study area where a reef-like habitat exists is in the northern end of Mosquito Lagoon at approximately 28°48′ N latitude. There the Intracoastal Waterway has been cut through limestone and/or coquina rock, leaving ledges with mild relief. It was not possible to make diving observations or poison collections on these ledges and it was impossible to adequately sample them with a trawl. Other than *Mycteroperca microlepis*, no reef-associated species have been collected in the area, although it is possible that a few others might be present.

(3) The depauperate estuarine fish fauna in the Cape Canaveral area is partially explained by reduced and indirect ocean-lagoon exchange. The 3 ocean inlets in the southern half of the lagoon system (St. Lucie, Ft. Pierce, and Sebastian inlets) are rather close together, within about 84 km; and ocean-lagoon interchange is rather direct. In contrast, the distance from the northern-most of these 3 southern inlets (Sebastian) to Ponce de Leon Inlet at the extreme northern end of the system is about 147 km. Ponce de Leon Inlet is about 28 km north of the northern limit of my study area and Sebastian Inlet is about 80 km south of the southern limit (Fig. 1).

Relative isolation of the northern part of the lagoon system was actually greater in the recent past than it is now. Haulover Canal, connecting the northern end of Indian River with Mosquito Lagoon, was first constructed in 1854 and was enlarged and relocated in 1888. Sebastian Inlet did not exist before 1886. It was cut several times between 1886 and 1918 but never remained open for more than a few days. The inlet was not dredged and stabilized until 1924 (Mehta et al., 1976). Prior to 1900, the most northern inlet south of Cape Canaveral was Indian River Inlet, a small natural cut at 27°30′ N latitude, about 4 km north of the present Ft. Pierce Inlet. Indian River Inlet closed in the early 1900s and Ft. Pierce Inlet was constructed in 1921 (Walton, 1974). The distance between Indian River Inlet and Ponce de Leon Inlet was almost 176 km. Thus, prior to 1921, opportunities for ocean-lagoon interchange in the Merritt Island area were severely limited and indirect.

Inlets enhance faunal diversity by providing species with oceanic affinities direct access to the lagoons. Such species may migrate regularly through inlets or may be wafted accidentally from ocean to lagoon by storms or strong tidal currents. Because inlet areas provide a variety of habitats, fish species diversity is also high around inlets (Gilmore, 1977a). Thus, inlets are both access routes for and sources of a variety of oceanic species that may enter the estuary to establish temporary or permanent populations. The long-term stability of many of these species in lagoon habitats probably depends on continual recruitment from the ocean through inlets (Gilmore and Hastings, 1983).

For marine species that spawn offshore, inlets provide direct access for the larvae or young to invade rich lagoon habitats. If the species involved have plaktonic larvae, the Gulf Stream (Florida Current) may transport them northward along the east coast of Florida from distant spawning sites. Because the Gulf Stream is nearer the coastline and inlets are more numerous and closer together at latitudes corresponding to the southern part of the estuary, tropical marine species, especially those with planktonic larvae, have a much greater chance of entering the estuary in the south. Once such species have gained lagoon access, the milder temperatures and more diverse habitats in the south increase the likelihood that they will persist.

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Academy Symposium

A CHECK-LIST OF THE PHYTOPLANKTON OF THE INDIAN RIVER NEAR VERO BEACH, FLORIDA

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Abstract: *The algal planktonic species from the Indian River near Vero Beach, Florida are presented as a check-list. Two-hundred-and-thirty species representing 68 genera of diatoms were observed. Twenty species of dinoflagellates from 9 genera are also listed from a year's collection.*

Scant information is available on the species of phytoplankton of the Indian River. Only cursory examinations of this flora were made as parts of larger ecological studies, by Stephens (1974, 1975) and David (1978). Stephens and Gibson (1979, 1980 a, b, c) have examined several epiphytic species of the diatom genus Mastogloia *from the Indian River, yet the phytoplanktonic flora was still undescribed.*

The phytoplanktonic assemblage of the Indian River near Vero Beach was examined as part of an interdisciplinary ecological study of the plankton of the Indian River. We provide a check-list of those algal species found.

Methods and materials—A station located in the Indian River (27°39.00′ N, 80°22.40′ W) was sampled weekly from 3 January 1977 to 3 January 1978. Further descriptions of this area, its hydrochemistry and phytoplankton ecology are in Mahoney and Gibson (1982). Water samples of approximately 30 ι volume were passed through a 20 μm mesh Nitex screen, the net plankton back-washed into a jar, fixed with glutaraldehyde and finally with 4% seawater-neutralized formalin. Other whole water samples of 100 ml volume were preserved in the same manner.

Subsamples of these collections were digested in 30% H_2O_2. After recovery on 0.45 m pore size Nucleopore filters and washed with distilled water, the digested material was placed in vials. Some of this material was dried on 12 mm dia. No. 1 coverglasses and permanent mounts were made using Hyrax (Custom Research and Development, Auburn, Calif., refractive index = 1.65).

Prepared slides were examined with a Zeiss Universal microscope using either bright field, dark field, phase contrast, or Nomarski differential interference contrast optics. Selected digested samples were also dried on 12 mm No. 1 coverslips and attached to aluminum stubs. These stubs were then gold-coated with a Denton DV-515 vacuum evaporator equipped with AutoSEM. Coated specimens were then examined with a Zeiss Novascan 30 scanning electron microscope at an accelerating voltage of either 15 or 30 kV.

More delicate species which would not withstand either digestion or drying were examined from the original glutaraldehyde and formalin-fixed sample with a Zeiss UPL inverted microscope. In many cases all 3 microscopes were used in a species identification.

Due to the uncertainty associated with the identification of the microflagellate organisms (Hasle and Smayda, 1960) no attempt was made at their classification beyond the general headings of Cryptophyceae, Chlorophyceae, Chrysophyceae, Euglenophyceae, Prasinophyceae and Unidentified. A complete listing of the taxonomic references used is beyond the scope of this report; however, several works which frequently used were: Hustedt (1933-1961), Schmidt (1874-1959), VanHeurck (1880-1885), Peragallo and Peragallo (1897-1908), Schiller (1933, 1937), Sournia (1973, 1978), and Steidinger and Williams (1970).

The phylogenetic scheme follows Simonsen (1979) for the diatoms and Schiller (1933) for the dinoflagellates.

Species Check-List

BACILLARIOPHYCEAE

ORDER CENTRALES

SUBORDER COSCINODISCINEAE

FAMILY THALASSIOSIRACEAE LEBOUR 1930, HASLE 1973

Cyclotella atomus Hust.
Cyclotella meneghiniana Kütz.
Cyclotella striata (Kütz.) Grun.
Skeletonema costatum (Grev.) Cl.
Skeletonema tropicum Cl.
Thalassiosira diporocyclus Hasle
Thalassiosira eccentrica (Ehr.) Cl.
Thalassiosira exigua Fryxell & Hasle
Thalassiosira gravida Cl.
Thalassiosira hyalina (Grun.) Gran
Thalassiosira minima Gaarder
Thalassiosira nanolineata (Mann) Fryxell & Hasle
Thalassiosira nordenskioeldii Cl.
Thalassiosira rotula Meun.
Thalassiosira spp.

FAMILY MELOSIRACEAE KÜTZING 1844

Corethron criophilum Castr.
Corethron hystrix Hensen
Hyalodiscus scoticus (Kütz.) Grun.
Hyalodiscus subtilis J. W. Bail.
Leptocylindrus danicus Cl.
Leptocylindrus minimus Gran
Melosira islandica O. Müll.
Melosira juergensii Ag.
Melosira moniliformis O. Müll.
Melosira nummuloides (Dillw.) Ag.
Paralia sulcata (Ehr.) Cl.
Podosira hormoides (Mont.) Kütz.
Podosira stelliger (J. W. Bail.) Mann

FAMILY COSCINODISCACEAE KÜTZING 1844

Coscinodiscus centralis Ehr.
Coscinodiscus granii Gough
Coscinodiscus nitidus Greg.
Coscinodiscus oculus-iridus Ehr.
Coscinodiscus radiatus Ehr.
Coscinodiscus spp.

FAMILY HELIOPELTACEAE H.L. SMITH 1872

Actinoptychus adriaticus var. *pumila* Grun.
Actinoptychus senarius Ehr.
Actinoptychus splendens (Shadb.) Ralfs
Actinoptychus sp.

SUBORDER RHIZOSOLENIINEAE

FAMILY RHIZOSOLENIACEAE PETIT 1888
Guinardia flaccida (Castr.) H. Perag.
Rhizosolenia alata Brightw.
Rhizosolenia calcar avis Schultze
Rhizosolenia delicatula Cl.
Rhizosolenia fragilissima Berg.
Rhizosolenia hebetata f. *semispina* (Hensen) Gran
Rhizosolenia imbricata Brightw.
Rhizosolenia minima Levan.
Rhizosolenia setigera Brightw.
Rhizosolenia stolterfothii H. Perag.

SUBORDER BIDDULPHIINEAE

FAMILY BIDDULPHIACEAE KÜTZING 1844
Biddulphia tridens Ehr. (= *B. tuomeyi* [Bail.] Roper)
Cerataulina pelagica (Cl.) Hend.
Cymatosira lorenziana Grun.
Eucampia cornuta (Cl.) Grun.
Hemiaulus hauckii Grun.
Hemiaulus sinensis (Grev.)
Terpsinoe americana (J.W. Bail.) Ralfs
Terpsinoe musica Ehr.
Trigonium alternans (Bail.) Mann
Trigonium reticulum (Ehr.) Simonsen

FAMILY CHAETOCERACEAE H.L. SMITH 1872
Bacteriastrum delicatulum Cl.
Bacteriastrum hyalinum Laud.
Chaetoceros affine Laud.
Chaetoceros affine var. *willei* (Gran) Hust.
Chaetoceros atlanticum Cl.
Chaetoceros breve Schutt
Chaetoceros cinctas Gran
Chaetoceros compressum Laud.
Chaetoceros constrictum Gran
Chaetoceros curvisetum Cl.
Chaetoceros danicum Cl.
Chaetoceros debile Cl.
Chaetoceros decipiens Cl.
Chaetoceros diadema (Ehr.) Gran
Chaetoceros didymum Ehr.
Chaetoceros didymum var. *angelica* (Grun.) Gran
Chaetoceros didymum var. *protruberans* Laud.
Chaetoceros diversum Cl.
Chaetoceros eibenii Grun.
Chaetoceros laciniosum Schutt
Chaetoceros lorenzianum Grun.
Chaetoceros messanense Castr.
Chaetoceros neogracile (Schutt) V.L.
Chaetoceros pelagicum Cl.
Chaetoceros peruvianum var. *gracile* (Schroder) Hust.
Chaetoceros pseudocurvisetum Mang.
Chaetoceros simplex Ostenf.
Chaetoceros subtile Cl.
Chaetoceros teres Cl.
Chaetoceros tortissimum Gran
Chaetoceros vistulae Apst.
Chaetoceros wighami Brightw.

FAMILY LITHODESMIACEAE H. & M. PERAGALLO 1897-1908
Bellerochea horologicalis von Stosch
Lithodesmium undulatum Ehr.
Streptotheca tamesis Shrub.

FAMILY EUPODISCAECEAE KÜTZING 1844
Auliscus caelatus var. *rhipis* A.S.
Auliscus caelatus var. *strigillata* A.S.
Auliscus puntatus J.W. Bail.
Auliscus reticulatus Grev.
Cerataulus smithii Ralfs
Cerataulus turgidus (Ehr.) Ehr.
Eupodiscus radiatus J.W. Bail.
Lampriscus shadboltianum Grev.
Odontella aurita (Lyngb.) Ag.
Odontella laevis (Ehr.) Kütz.
Odontella longicruris (Grev.)
Odontella mobiliensis (Bail.) Grun.
Odontella obtusa Kütz.
Odontella rhombus (Ehr.) Kütz.
Odontella sinensis (Grev.) Grun.
Triceratium antediluvianum (Ehr.) Grun.
Triceratium dubium Brightw.
Triceratium favus Ehr.
Triceratium favus f. *quadrata* Grun.
Triceratium pentacrinus (Ehr.) Wallich
Triceratium pentacrinus f. *quadrata* Temp. & Perag.

ORDER PENNALES

SUBORDER ARAPHIDINEAE

FAMILY DIATOMACEAE DUMORTIER 1822
Asterionella glacialis Castr.
Asterionella kariana Grun.
Asterionella notata Grun.
Falcula media Voigt?
Fragilaria capucina var. *mesolepta* Rabh.
Fragilaria oceanica Cl.

SUBORDER ARAPHIDINEAE (Continued)

Fragilaria virescens var. *mesolepta* Rabh.
Fragilaria spp.
Grammatophora marina (Lyngb.) Kütz.
Grammatophora marina var. *tropica* (Kütz.) Grun.
Grammatophora oceanica (Ehr.) Grun
Grammatophora oceanica var. *macilenta* (W. Sm.) Grun.
Grammatophora serpentina (Ralfs) Ehr.
Licmophora abbreviata Ag.
Licmophora ehrenbergii (Kütz.) Grun.
Licmophora spp.
Opephora marina (Greg.) Petit
Opephora martyi Herb.
Opephora pacifica (Grun.) Petit
Opephora schwartzi (Grun.) Petit ex. Pell.
Plagiogramma interruptum (Greg.) Ralfs
Plagiogramma van heurckii Grun.
Plagiogramma sp.
Raphoneis adriaticum Kütz.
Raphoneis amphiceros (Ehr.) Ehr.
Raphoneis amphiceros var. *gemmifera* (Ehr.) Perag. & Perag.
Raphoneis castracanei Grun.
Raphoneis surirella (Ehr.) Grun.
Raphoneis sp.
Rhabdonema adriaticum Kütz.
Striatella unipunctata (Lyngb.) Ag.
Synedra fulgens (Grev.) W. Sm.
Synedra hennedyana Greg.
Synedra pulcherrima Hantz.
Synedra robusta Ralfs
Synedra tabulata (Ag.) Kütz.
Synedra tabulata var. *fasiculata* (Kütz.) Grun.
Synedra spp.
Thalassionema nitzschioides (Grun.) V.H.

FAMILY ACHNANTHACEAE KÜTZING 1844
Achnanthes brevipes Ag.
Achnanthes delicatula (Kütz.) Grun.
Achnanthes fimbriata (Grun.) Ross
Achnanthes hauckiana Grun.
Achnanthes lanceolata var. *elliptica* Cl.
Achnanthes longipes Ag.
Achnanthes sp.
Anorthoneis eccentrica (Donk.) Grun.
Cocconeis disculoides Hust.
Cocconeis pseudomarginata Greg.
Cocconeis scutellum Ehr.
Cocconeis spp.

FAMILY NAVICULACEAE KÜTZING 1844
Amphora arenaria Donk.
Amphora decussata Grun.
Amphora exigua Greg.
Amphora marina V.H.
Amphora robusta Greg.
Amphora sp.
Anomoeoneis sphaerophora var. *sculpta* Ehr.
Berkeleya rutilans (Trentepohl) Grun.
Carpartogramma crucicula (Grun. ex Cl.) Ross
Cymbella sp.
Dictyoneis mastogloidia (Pant.) Cl.
Dimerogramma minor (Greg.) Ralfs
Diploneis bombus Ehr.
Diploneis crabro (Ehr.) Ehr.
Entomoneis alata (Ehr.) Ehr.
Entomoneis pulchra (J.W. Bail.) Reim.
Gomphonema acuminatum Ehr.
Gyrosigma baileyi (Grun.) Cl.
Gyrosigma balticum (Ehr.) Rabh.
Gyrosigma hummii Hust.
Mastogloia cribosa Grun.
Mastogloia crucicula (Grun.) Cl.
Mastogloia exigua Lewis
Mastogloia smithii Thw. ex W. Sm.
Mastogloia splendida (Greg.) Cl. & Möller
Navicula approximata Grev.
Navicula directa (W. Sm.) Ralfs
Navicula granulata J.W. Bail.
Navicula lyra Ehr.
Navicula lyra var. *atlantica* A.S.
Navicula scopulorum Bréb.
Navicula transfuga var. *plagiostoma* (Grun.) Cl.
Navicula spp.
Pinnularia gentilis (Donk.) Cl.
Pinnularia robusta Hust.
Plagiotropis lepidoptera var. *proboscidea* (Cl.) Reim.
Pleurosigma delicatulum W. Sm.
Pleurosigma elongatum var. *gracilis* Grun.
Pleurosigma spp.
Stauroneis amphoroides Grun.
Trachyneis aspera Ehr.

FAMILY EPITHEMIACEAE GRUNOW 1860
Epithemia sorex Kütz.
Rhopalodia gibberula (Grun.) Mayer

FAMILY NITZSCHIACEAE GRUNOW 1860
Cylindrotheca closterium (Ehr.) Reimann & Lewin
Nitzschia fronticola Grun.
Nitzschia frustulum var. *subsalina* Hust.
Nitzschia insignis Greg.
Nitzschia linearis W. Sm.
Nitzschia longissima (Bréb.) Grun.
Nitzschia lorenziana var. *subtilis* Grun.
Nitzschia panduriformis Greg.

SUBORDER ARAPHIDINEAE (Continued)

Nitzschia parvula W. Sm.
Nitzschia pungens Grun.
Nitzschia reversa W. Sm.
Nitzschia seriata Cl.
Nitzschia sigma (Kütz.) W. Sm.
Nitzschia sigma var. *intercedens* Grun.
Pseudonitzschia delicatissima (Cl.) Heid.

FAMILY SURIRELLACEAE KÜTZING 1844
Surirella gemma Ehr.

DESMOKONTAE

ORDER THECATALES

FAMILY PROROCENTRACEAE PASCHER 1914
Prorocentrum baltica (Lohm.) Abe
Prorocentrum maximum Schiller
Prorocentrum micans Ehr.
Prorocentrum minimum Schiller

ORDER DINOPHYSIALES

FAMILY DINOPHYSIACEAE PAVILLARD 1916
Dinophysis argus (Stein) Abe
Dinophysis caudata Saville-Kent
Dinophysis caudata var. *acutifrons* Kofoid & Skog.
Dinophysis micropterygia Dang.
Dinophysis parvulum (Schutt) Abé

DINOPHYCEAE

ORDER GYMNODINIACEAE

FAMILY GYMNODINIACEAE PASCHER 1914
Amphidinium sp.
Gymnodinium spp.

ORDER PERIDINIALES

FAMILY PERIDINIACEAE (BERGH) BALECH 1967
Protoperidinium pellucidum Balech

FAMILY GONIAULACACEAE LINDEMANN 1928
Gonyaulax birostris Stein
Gonyaulax diacantha (Meun.) Schiller
Gonyaulax polygramma Stein
Gonyaulax spp.

FAMILY HETERODINIACEAE LINDEMANN 1928
Ceratium contrarium (Gour.) Pavill.
Ceratium furca (Ehr.) Clap. & Lach.
Ceratium fusus (Ehr.) Dujardin
Ceratium hircus Schroeder
Ceratium teres Kofoid
Ceratium tripos (O.F. Müll.) Nitzsch
Ceratium tripos var. *pullchellum* Schroder

CHRYSOPHYCEAE

Dictyocha fibula Ehr.
Distephanus crux (Ehr.) Haeckel
Distephanus speculum (Ehr.) Haeckel

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PHYTOPLANKTON ECOLOGY OF THE INDIAN RIVER NEAR VERO BEACH, FLORIDA

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ABSTRACT: *The average, annual total phytoplankton cell density in the Indian River near Vero Beach was* 1.38×10^{10} *cells* m^{-3} *and the average net* ($>20\ \mu m$) *phytoplankton cell density was* 9.88×10^{7} *cells* m^{-3}. *Average total chlorophyll* a *for the year was 10.69 mg* m^{-3} *and 3.42 mg* m^{-3} *for the total and net fractions respectively. This portion of the river was characterized by relatively high nutrient concentrations. Yearly mean values for total nitrogen, orthophosphate and silicate were 9.24 μM, 1.79 μM and 53.67 μM, respectively. Most biological standing stock belonged to the phytoplankton size fraction passing through a 20 μm mesh net. These nanophytoplankton accounted for 99.3% of the cell density, 90.7% of the biomass and 78.0% of the active chlorophyll* a *observed throughout the year study. Variations in diatom cell densities accounted for most total phytoplankton cell density fluctuations.* Skeletonema costatum *(Grev.) Cl. was the dominant diatom in terms of numbers and biomass. The initial spring bloom was comprised mainly of relatively small chain-forming diatom species of the genera* Chaetoceros, Nitzschia *and* Thalassiosira. *This pulse was followed by a period of increased phytoflagellate and dinoflagellate numbers. The diatom genera during this period were* Thalassiosira, Nitzschia *and* Skeletonema. *The late summer-fall phytoplankton community was primarily composed of* Chaetoceros, *phytoflagellates,* Thalassiosira, Skeletonema *and* Paralia. *The late fall-winter phytoplankton community was dominated by phytoflagellates and a diatom assemblage comprised of* Thalassiosira, Nitzschia *and* Skeletonema.

IN biological systems, organisms with the shortest generation times are more sensitive to changes in the environment than are organisms with long generation times, and as a general rule the smaller the organism, the shorter the generation time (Braarud, 1945; Semina, 1969; Malone, 1971). For this reason we examine the autotrophic phytoplankton component of the Indian River, as opposed to larger organisms in higher trophic levels.

The Indian River is a bar-built, lagoonal estuary located on the central, east-coast of Florida. It extends approximately 195 km from Cape Canaveral in the north to Stuart in the south. The Indian River has 4 open communications with the Atlantic Ocean: St. Lucie Inlet, Ft. Pierce Inlet, Sebastian Inlet, and an indirect connection through Haulover Canal and Mosquito Lagoon to Ponce de Leon Inlet (Fig. 1). It is a shallow (average depth 2m) body of water dotted with numerous islands and islets. The river contains extensive regions of seagrass beds and mangrove swamps.

Several phytoplankton studies have been conducted in various parts of the Indian River (Stephens, 1975, 1976; Barbaccia, 1977; Youngbluth et al., 1977; David, 1978). These studies have emphasized net phytoplankton (organisms retained by a net) and ignored the nanophytoplankton (organisms passing through a net).

Recently, there has been increased attention given to phytoplankton size classes, the distribution of biomass in these size classes and the inadequacy of cell abundance data alone as a measure of phytoplankton standing stock. A number of studies have been conducted using screens or filters to obtain estimates of biomass, chlorophyll or productivity values for various

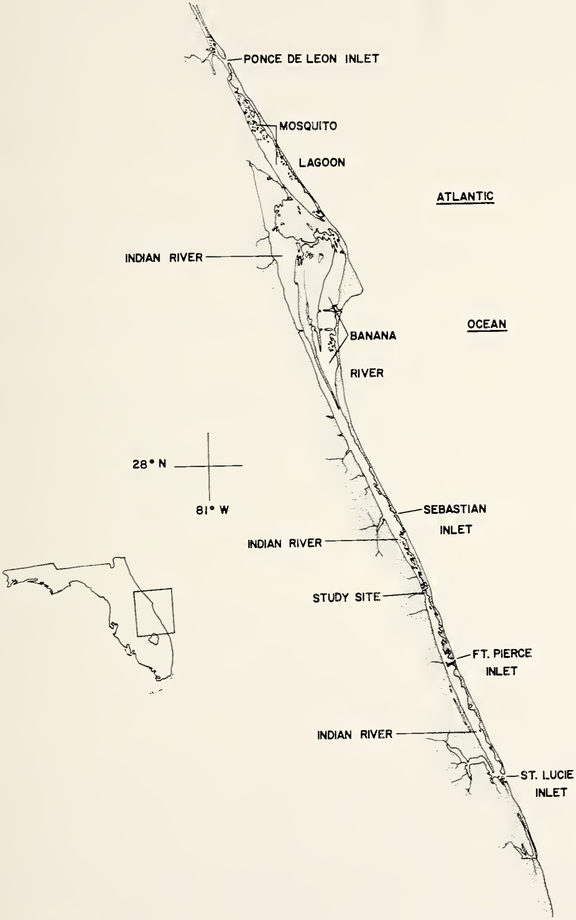

FIG. 1. Map of study area.

phytoplankton size fractions (Holmes and Anderson, 1963; Van Valkenburg and Flemer, 1974; Throndsen, 1978; Gilmartin and Revelante, 1978; Malone and Chervin, 1979; Hallegraeff, 1981). These studies indicate most autotrophic production occurs in the size fraction loosely referred to as the nanophytoplankton (i.e., the smaller organisms that pass through a fine mesh net; usually ranging 20-35 μm, depending on the individual study).

Size of organisms is an important factor in a number of processes. Metabolic activity (Banse, 1976), sinking rates (Eppley et al., 1967; Smayda, 1970) and nutrient uptake kinetics (Eppley et al., 1969) have been shown to be affected by cell size. Most filter-feeders and herbivorous zooplankton are size-selective grazers (Mullin, 1963; Martin, 1970; Wilson, 1973). Measurement of biological activity and biomass distribution in the different size fractions contributes to understanding the important initial steps of energy flow through the planktonic trophic levels.

We present part of a study on the temporal changes occurring in the autotrophic phytoplankton component of the aquatic community in the Indian River at Vero Beach, Indian River County, Florida. Our objective was to evaluate the importance of the net and nano size fractions of the autotrophic phytoplankton community.

MATERIALS AND METHODS—Our study site in the Indian River was 0.137 km south of Vero Beach bridge (27°39.00′ N, 80°22.40′ W). The study area was unaffected by direct tidal flushing and is typical of most areas in the Indian River.

We define net phytoplankton as that size fraction of the autotrophic phytoplankton assemblage retained by a 20 μm mesh net. Total phytoplankton is defined as the entire unfractionated autotrophic phytoplankton assemblage.

Weekly collections were made from 3 January 1977 to 3 January 1978. Net phytoplankton collections were made using an integrated water column pipe sampler (Youngbluth, et al. 1977). This sampler effectively samples and integrates a water column up to 4.5 m in depth. Approximately 30 ι of water drawn from 2 pipe samples was passed through a 20 μm mesh Nitex screen and collected in a graduated carboy. After recording the volume of water filtered, the retained net phytoplankton was back-washed into a jar, fixed with glutaraldehyde, and preserved with a borate buffered 4% formalin solution. This procedure was repeated twice to provide triplicate, net phytoplankton samples.

Total phytoplankton collections were made using the integrated water column pipe sampler. Two pipe samples were collected and drained into a carboy. After thorough mixing, an aliquot was withdrawn for total phytoplankton analysis. The sample was then fixed with glutaraldehyde and preserved with 4% seawater-neutralized formalin. This procedure was repeated 3 times to provide quadruplicate total phytoplankton samples.

Aliquots were also withdrawn for the analysis of nutrients and pigments. Nutrient analyses for nitrate, nitrite, ammonia, orthophosphate and silicate were carried out with a Technicon AutoAnalyzer Model AA II. Operation, methods and quality control of the Technicon AutoAnalyzer AAII are detailed by Zimmermann et al. (1977). Salinity and water temperature were recorded in the field using a multi-parameter array probe unit (Hydro-Lab Surveyor Model 6D).

Samples for pigment analysis were taken in triplicate. Two separate pigment analyses were run: one for total phytoplankton pigments and one for nanophytoplankton pigments. The total phytoplankton pigment analysis was performed on the unfractionated total phytoplankton assemblage. The samples were filtered using a Millipore manifold apparatus and collected on 47 mm dia, 0.40 μm pore size Nucleopore filters. The nanophytoplankton pigments were prefiltered through a 20 μm mesh Nitex screen and then collected on 47 mm dia, 0.40 μm pore size Nucleopore filters. Removal of the net phytoplankton size component via pre-screening provided a direct value for the nanophytoplankton component. Samples were analyzed using the methods of Strickland and Parsons (1960) as modified by the SCOR-UNESCO Working Group 17

(Anonymous, 1966). A model 635 Varian spectrophotometer using either 5 cm or 10 cm pathlength cells was used for these analyses. The spectrophotometer was calibrated using Standard Reference Material 930c, Glass Filters for Spectrophotometry, Filter and Set Identification Numbers 1-489, 2-489 and 3-489 supplied by the National Bureau of Standards. Transmission and absorbance were checked at 440.0 nm, 465.0 nm, 546.1 nm, 590.0 nm and 635.0 nm.

Both the net and total phytoplankton samples were examined by the inverted microscope technique (Utermöhl 1931, 1958). The samples were placed in 25.4 mm dia Zeiss plate chambers holding 2.124 ml and allowed to settle for 2 hr. After settling, organisms were counted and examined at either 400x or 1000x using a Zeiss Invertoscope D inverted microscope equipped with phase contrast, brightfield and darkfield optics. Members of the phytoplankton assemblage were identified to species where possible and then categorized under the headings of diatoms, dinoflagellates, flagellates and others. The number of organisms to be counted was determined to maintain a minimum 80% confidence level of the species present in each collection (Student, 1908; Fisher, 1926).

Subsequent to enumeration and identification, both sets of phytoplankton samples were analyzed for cell volume. Due to the almost infinite variability of phytoplankton cell shapes, the process of cell volume determination must, by necessity, include a subjective flexibility on the part of the investigator. Ideally, a separate volume equation should exist for each species and cell configuration. As this is effectively impossible, it was decided to use 7 basic geometric shapes and combinations of these shapes to represent the observed cell shapes (i.e., sphere, ellipsoid, cone, cylinder, elliptical cylinder, wedge and rectangular solid).

Upon observation of a cell, it was determined which shape or combination of shapes best represented the observed cell. The shape decided upon was then recorded and the dimensions necessary to calculate the cell volume measured using an eyepiece micrometer. Measurements in the Z-plane were made using a calibrated micrometer stage. Cells were measured as encountered on random passes across the plate chamber. The number of cells to be measured was determined by using a power function analysis (Neyman et al., 1935).

Rainfall records were obtained from Vero Beach Laboratories, Mobay Agricultural Chemicals Division. The rainfall data are expressed as the amount of rain (in cm) that fell in the week prior to the cruise date. Solar insolation data were collected with an Eppley pyroheliometer Model 8-48 located at Harbor Branch Foundation. The solar insolation data are expressed as the average number of Langleys (g-cal cm^{-2}) per day for the week preceding each cruise.

Material and slide collections are on deposit in the Harbor Branch Foundation Herbarium, Ft. Pierce, Florida (HBFH D-173 through HBFH D-213, and HBFH D-534 through HBFH D-547).

RESULTS — Monthly mean values for physical-chemical and cell data are presented in Tables 1 and 2.

Solar Insolation and Water Temperature: Water temperature and solar insolation depict a typical bell-shaped curve with maximum values occurring in the June through September (Fig. 2). Throughout the study, the water temperature curve lagged approximately 1 wk behind the solar insolation curve. A notable exception occurred during the fall storm season when the water temperature lagged far behind the drastically-reduced solar insolation.

Rainfall and Salinity: The curves depicting salinity and rainfall (Fig. 3) show a negative relationship. Increased rainfall during the early summer and fall led to 2 extended periods of decreased salinity: 31 May to 18 July and 15 August to 3 October; with mean salinities during these periods of 27.4 ‰ and 25.1 ‰, respectively.

Orthophosphate and nitrogen: Orthophosphate and total nitrogen values are in Fig. 4. The curves show a positive relationship with rainfall. This pattern of nutrient fluctuation with increased rainfall was maintained throughout the year. Most nitrogen was in the form of ammonia.

TABLE 1. Monthly mean values for rainfall, solar radiation, temperature, salinity, and nutrients.

Month	Rainfall (cm week^{-1})	Insolation (Langleys day^{-1})	Temperature (°C)	Salinity (°/oo)	Silicate (μM)	Phosphate (μM)	Nitrite (μM)	Nitrate (μM)	Ammonia (μM)	Total Nitrogen (μM)
January	1.43	282.30	15.4	27.84	18.88	0.77	0.13	1.14	2.26	3.53
February	0.40	331.49	16.1	28.33	13.02	0.63	0.22	0.74	2.46	3.42
March	0.65	425.87	22.9	30.32	31.30	0.93	0.10	0.90	2.67	3.67
April	0.56	527.62	24.4	35.00	26.86	0.89	0.17	1.57	2.51	4.25
May	1.58	519.92	26.1	35.20	25.11	1.03	0.19	1.05	3.05	4.29
June	6.75	491.07	28.9	26.31	86.22	4.88	0.48	22.09	15.83	38.40
July	1.53	528.48	30.4	27.50	143.05	3.98	0.20	0.82	6.46	7.48
August	2.71	483.11	29.4	33.90	42.09	1.43	0.15	0.82	3.40	4.37
September	4.09	412.79	30.0	24.01	120.19	2.66	0.34	4.05	11.29	15.68
October	1.44	392.88	24.7	29.00	60.23	2.00	0.18	1.42	10.09	11.69
November	1.65	301.49	20.9	31.50	35.65	1.57	0.18	1.48	5.16	6.82
December	3.74	232.84	17.9	26.20	53.89	1.23	0.34	2.06	7.27	9.67

TABLE 2. Monthly mean values: cell data.

Month	Cell Density (cells m^{-3})	Cell Size (μm^3)	Biomass (μm^3 m^{-3})	Live Chlorophyll *a* (mg m^{-3})
Total Phytoplankton				
January	4.54×10^{9}	3.85×10^{3}	2.12×10^{12}	2.21
February	2.46×10^{9}	2.84×10^{3}	8.33×10^{11}	1.73
March	9.12×10^{9}	1.19×10^{3}	2.01×10^{12}	5.72
April	2.52×10^{10}	2.12×10^{2}	3.30×10^{12}	10.53
May	2.02×10^{10}	2.39×10^{2}	2.71×10^{12}	9.64
June	2.16×10^{10}	1.62×10^{2}	2.06×10^{12}	15.63
July	1.94×10^{10}	2.43×10^{2}	2.29×10^{12}	12.55
August	1.71×10^{10}	3.14×10^{2}	1.29×10^{12}	8.30
September	1.60×10^{10}	1.98×10^{2}	1.48×10^{12}	9.98
October	1.65×10^{10}	2.99×10^{2}	2.02×10^{12}	7.38
November	6.92×10^{9}	1.05×10^{3}	5.38×10^{11}	2.22
December	5.88×10^{9}	1.46×10^{3}	1.07×10^{12}	2.51
Net Phytoplankton				
January	1.62×10^{7}	1.03×10^{4}	1.75×10^{11}	0.64
February	2.33×10^{7}	7.63×10^{3}	1.40×10^{11}	0.23
March	8.87×10^{6}	1.46×10^{4}	1.10×10^{11}	1.47
April	4.21×10^{7}	4.88×10^{3}	1.15×10^{11}	2.87
May	4.74×10^{8}	9.29×10^{2}	3.94×10^{11}	2.97
June	4.34×10^{8}	2.20×10^{2}	1.35×10^{11}	6.03
July	2.67×10^{7}	1.70×10^{3}	4.71×10^{10}	1.15
August	1.82×10^{7}	7.10×10^{3}	6.80×10^{10}	0.62
September	9.23×10^{6}	1.06×10^{4}	6.27×10^{10}	0.70
October	4.04×10^{7}	3.96×10^{3}	8.49×10^{10}	0.62
November	2.31×10^{7}	4.82×10^{4}	5.89×10^{11}	0.84
December	1.07×10^{7}	1.23×10^{4}	1.35×10^{11}	0.82

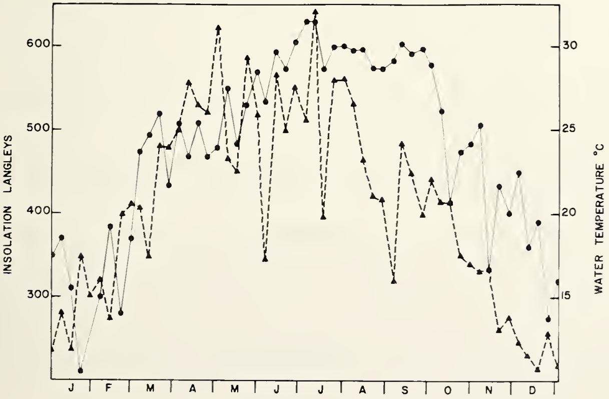

FIG. 2. Solar Insolation—water temperature. Insolation (triangles and dashed line) water temperature (circles and solid line).

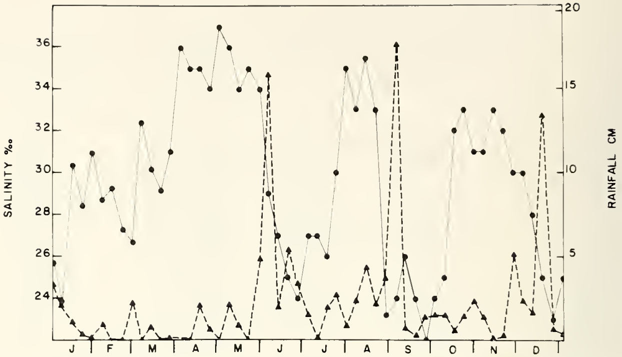

FIG. 3. Salinity—rainfall. Salinity (circles and solid line) rainfall (triangles and dashed line).

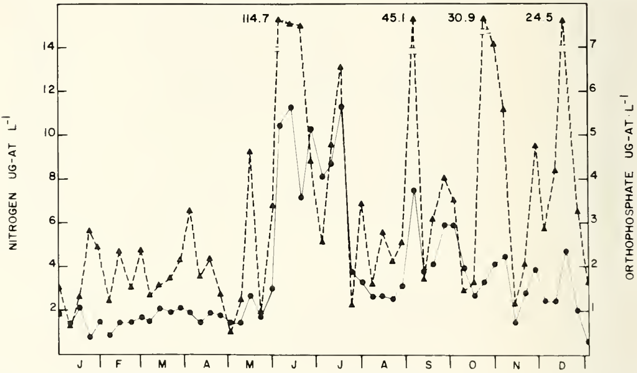

FIG. 4. Orthophosphate—total nitrogen. Orthophosphate (circles and solid line) total nitrogen (triangles and dashed line).

Silicate: Silicate values (Fig. 5) varied in direct response to increased rainfall. High silicate values occurred during the 2 summer-fall periods of increased rainfall.

Species Composition and Cell Density: We found 230 species of diatoms representing 68 genera, and 20 species of dinoflagellates of 9 genera. Due to the uncertainty associated with the identification of the microflagellate organisms of the phytoplankton community (Hasle and Smayda, 1960), all microflagellate cell densities were consolidated under the heading of flagellates for the purpose of community analysis. A species list is provided in Mahoney and Gibson (1982).

Net phytoplankton: The net phytoplankton assemblage (Fig. 6) during the first part of the study period (3 January-4 April) was dominated by the

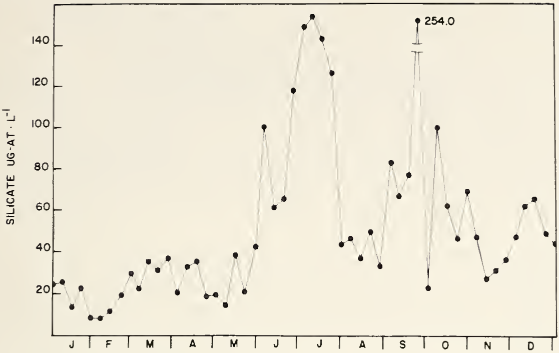

FIG. 5. Silicate concentrations.

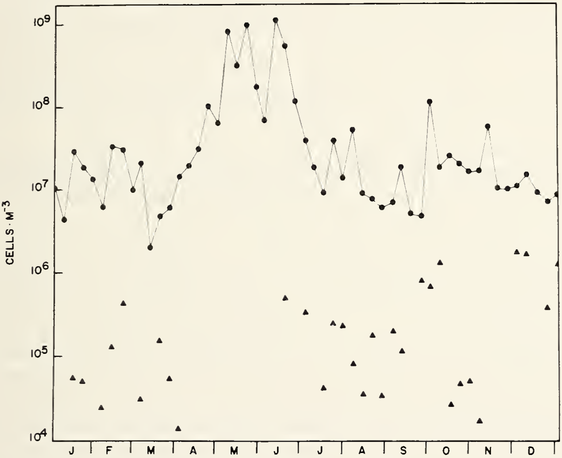

FIG. 6. Net phytoplankton abundance. Diatoms (circles) dinoflagellates (triangles).

following diatoms: *Bacillaria paxillifer* Gmelin, *Melosira moniliformis* (O. Müll.), *Paralia sulcata* (Ehr.) Cl., *Skeletonema costatum* (Grev.) Cl., and *Thalassiosira rotula* Meunier. This time period was one of relatively low temperatures and low salinities characteristic of Florida winters.

The net phytoplankton assemblage from 11 April to 9 May was dominated by a large, rapidly increasing population of diatoms of the genera *Chaetoceros* and *Thalassiosira*. At times the diatom assemblage contained as many as 13 species of the genus *Chaetoceros*, the most common of which were: *Chaetoceros affine* Laud., *C. compressum* Laud., *C. curvisetum* Cl., *C. decipiens* Cl., *C. laciniosum* Schütt, *C. neogracile* (Schütt) V. L. and *C. teres* Cl. This early summer period was typified by increasing water temperatures, elevated salinities and increased cell density.

From 13 May to 27 June, the net phytoplankton assemblage was dominated by the diatom *Skeletonema costatum*, with several species of *Chaetoceros* as secondary dominants. Heavy rainfall occurred during this period causing unusually high nutrient values. The maximum cell density for the net phytoplankton component (1.41 x 10^9 cells m^{-3}), 13 June, occurred during this time and was comprised almost solely of the diatom *Skeletonema costatum*.

Beginning on 5 July, the net phytoplankton was again dominated by a mixture of diatoms of the genus *Chaetoceros* along with *Bacillaria paxillifer*, *Paralia sulcata*, *Thalassiosira binata* G. Fryxell, *Thalassiosira diporocyclus* Hasle, *Thalassiosira minima* Gaar and *Thalassiosira exigua* Fryxell et Hasle. This assemblage dominated the net phytoplankton through 10 October. This late summer-fall period in Florida is characterized by elevated water temperatures, increased rainfall and subsequent salinity fluctuations.

The water temperature, salinity and cell densities all decreased in the late fall-winter season (5 December to 3 January). The dominant net phytoplankton organisms for this period were the diatoms *Thalassiosira eccentrica* (Ehr.) Cl., *Bacillaria paxillifer*, and *Paralia sulcata*.

The net phytoplankton cell density over the entire study period ranged from a low value of 2.05 x 10^6 cells m^{-3} (14 March) to a high value of 1.41 x 10^9 cells m^{-3} (13 June). The mean net phytoplankton cell density for the entire study period was 9.88 x 10^7 cells m^{-3}.

Total phytoplankton: The pattern of succession for the total phytoplankton assemblage exhibited a marked difference from that of the net phytoplankton assemblage. Because of the difference in the method of collection, the minimum detection levels for the total and net collections were also different. Due to the concentrating effect of the net method, it was possible to detect species present at a much lower frequency than would be possible using the total method. The minimum detection levels for the total and net methods were 1.72 x 10^7 and 1.10 x 10^4 cells m^{-3}, respectively.

During the first 6 wk of the study period extending from 3 January to 7 February (Fig. 7), the total phytoplankton assemblage was dominated by a mixture of flagellates and the diatom *Skeletonema costatum*. Beginning on 14 February, the diatom *Thalassiosira rotula* began to replace *Skeletonema costatum*. By 22 February, *Thalassiosira rotula* was the second most abundant organism. This condition prevailed from 22 February to 14 March.

The population of 21 March was marked by the occurrence of the diatom *Thalassiosira eccentrica* as the most abundant organism. The second most abundant group were the flagellates, followed by the diatom *Nitzschia delicatissima*. This change in dominance from flagellates to diatoms occurred simultaneously with a 1 order-of-magnitude increase in diatom cell densities. Flagellate cell densities however, did not decrease during this

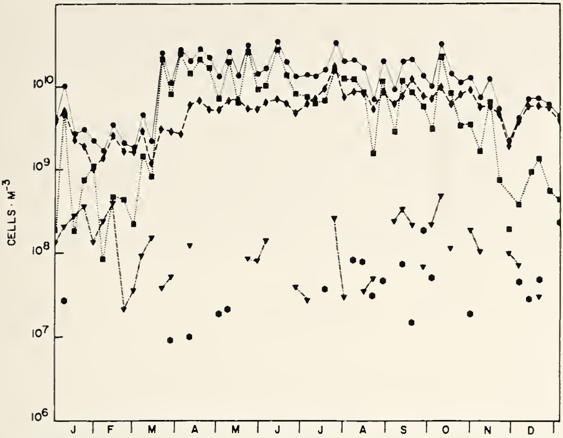

FIG. 7. Total phytoplankton abundance. Total (circles) diatoms (squares) flagellates (diamonds) dinoflagellates (triangles) other (hexagons).

period. This dramatic increase in diatom cell densities seems to be associated with the abrupt increase in solar insolation and water temperature.

The total phytoplankton assemblage, from 28 March to 18 April, was dominated by the diatom *Nitzschia delicatissima* and *Thalassiosira eccentrica* followed by flagellates. During 25 April to 6 June, the total phytoplankton was dominated by a mixture of the diatom *Thalassiosira eccentrica* and flagellates. The secondary component of this assemblage was composed of a mixture of *Chaetoceros compressum*, *C. affine*, *C. laciniosum*, and an increasing population of *Skeletonema costatum*.

From 6 June to 27 June, the diatom *Skeletonema costatum* exhibited a remarkably high standing crop in response to a massive nutrient influx evidently initiated by heavy rainfall. This resulted in the highest cell densities encountered during the study. This population, which occurred on 13 June, had a density of 3.56 x 10^{10} cells m^{-3}, and was comprised almost entirely of the diatom *Skeletonema costatum*.

The sample of 5 July marks the emergence once again of flagellates as the most numerous organisms. The total phytoplankton was dominated by the flagellates, followed by the diatoms *Thalassiosira binata* and a greatly reduced population of *Skeletonema costatum*. The total phytoplankton assemblage remained much the same from 5 July to 10 October. On 2 occasions, 5 July and 10 October, the diatom *Thalassiosira binata* was the most abundant organism. This time period corresponded to the warm months of late summer-fall.

The period of time extending from 17 October to 3 January corresponded to the late fall-winter season with decreasing solar insolation and water temperature. During this period the total phytoplankton was heavily dominated by flagellates with a secondary assemblage comprised of *Thalassiosira eccentrica*, *Nitzschia delicatissima*, *Skeletonema costatum* and *Skeletonema tropicum* Cl.

Over the entire study period, the total phytoplankton cell densities ranged from a low value of 1.72 x 10^9 cells m^{-3} (7 February) to a high value of 3.56 x 10^{10} cells m^{-3} (13 June). The mean total phytoplankton cell density for the entire study period was 1.38 x 10^{10} cells m^{-3}.

Biomass and Cell Size: Cell volumes were computed as a relative measure of abundance and biomass and are presented as the total cell volume per m^3 of water.

NET PHYTOPLANKTON. Ninety-eight percent of the net phytoplankton (Fig. 8 & 9) was diatoms in both numbers and cell volume. Fig. 8 shows a relatively stable biomass level with generally higher values in the colder time periods. The early portion of the study period, 3 January, 1977 to 4 April, was characterized by moderate cell density and large mean cell volume (Fig. 9). The period from 11 April to 9 May was characterized by increasing cell densities, decreasing cell size, and a slight increase in biomass.

The period from 16 May to 11 July is manifested by high standing stock, high nutrient values, increased cell densities, decreased cell size, and decreased biomass. The lowest biomass values for the net phytoplankton study (3.20 x 10^9 μm^3 m^{-3}) occurred on 11 July.

Stable summer conditions occurred from 18 July to 27 September. Relative to the previous time period, cell density decreased, cell size increased and biomass decreased. The increased average cell size was the result of the appearance of *Paralia sulcata* and *Coscinodiscus oculus-iridis*, both large diatoms.

The end of the study period, 3 October to 3 January 1978, corresponds to decreasing water temperature. Wide variations were observed in the mean cell volumes and biomass of the net phytoplankton. A large portion of this variation was due to the appearance of a very large diatom (*Coscinodiscus granii* Gough). For this final portion of the study the mean cell density increased, the mean cell volume increased and the mean biomass increased.

For the entire study, net phytoplankton biomass ranged from a low value of 3.18 x 10^9 μm^3 m^{-3} (11 July) to a high value of 1.04 x 10^{12} μm^3 m^{-3} (28 November). The mean cell size ranged from a low value of 1.70 x 10^2 μm^3 (11 July) to a high value of 1.05 x 10^5 μm^3 (28 November).

TOTAL PHYTOPLANKTON. The first part of the study period (3 January, 1977 to 14 March) contained wide variations in both the cell density and biomass (Fig. 10).

The period from 21 March to 27 June corresponded to spring-early summer conditions. It was a time of increasing water temperatures, increasing cell densities and biomass and decreasing cell size. This period was dominated by a rapidly increasing standing stock comprised of small

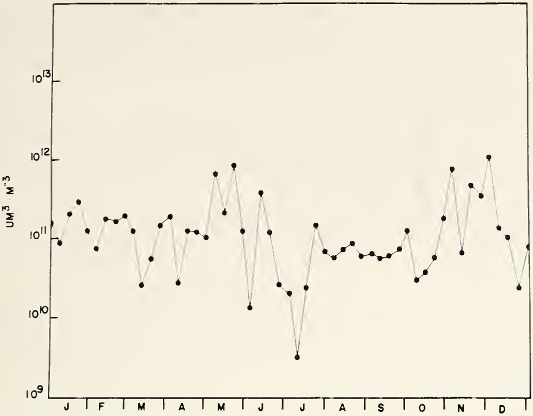

FIG. 8. Net phytoplankton biomass.

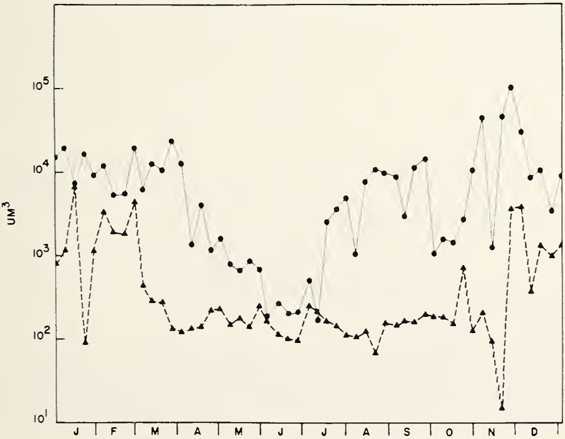

FIG. 9. Net and total phytoplankton mean diatom cell volume. Net phytoplankton diatoms (circles and solid line); total phytoplankton diatoms (triangles and dashed line).

diatoms, notably the genera *Thalassiosira*, *Chaetoceros* and *Skeletonema*. From 5 July to 10 October, cell densities decreased relative to the previous period. The biomass value decreased only slightly, while phytoplankton cell size increased slightly.

The final portion of the study period corresponded to the late fall-winter period and lasted from 17 October to 3 January 1978. During this time span there was a large decrease in the flagellate cell densities, biomass decreased slightly, and mean cell size increased.

Total phytoplankton biomass ranged from a low value of 9.63×10^{10} μm^3 m^{-3} on 21 November to a high value of 7.18×10^{12} μm^3 m^{-3} on 10 January with a mean for the year of 1.82×10^{12} μm^3 m^{-3}.

The mean biomass for the entire study for net phytoplankton size fraction was 1.71×10^{11} μm^3 m^{-3} and the mean biomass for the total phytoplankton size fraction was 1.83×10^{12} μm^3 m^{-3}. Expressed differently, the net phytoplankton accounted for an average of only 9.3% of the total phytoplankton biomass observed.

Active Chlorophyll a: The pigment component measure was active chlorophyll *a*. This is the total chlorophyll *a* value corrected for the degradation products present (Strickland and Parsons, 1960; Anonymous, 1966).

The active chlorophyll *a* values were relatively low from 3 January 1977 to 7 March (Fig. 11). These low active chlorophyll *a* values corresponded to low water temperatures and low solar insolation values typical of Florida winters.

From 14 March to 18 July, both solar insolation and water temperature values increased with a subsequent increase in active chlorophyll *a* values. During this period there was a relative increase in the active chlorophyll *a* content of the net phytoplankton. This increase was due almost exclusively to the abundant diatom flora present. This diatom flora was comprised principally of small chain-forming diatoms, notably members of the genera *Chaetoceros* and *Skeletonema*. The highest active chlorophyll *a* values of the study period occurred at this time.

From 25 July to 29 August, there was a decrease in the active chlorophyll *a* values in both size fractions, with most of the active chlorophyll *a* in the nanophytoplankton size fraction.

Warm-water conditions, from 6 September to 3 October, were correlated with wide variations in the active chlorophyll *a* values. The nano, total active chlorophyll *a* values, solar insolation, and water temperature decreased from 10 October to 3 January 1978.

The values for nanophytoplankton active chlorophyll *a* ranged from a low of 0.70 mg m^{-3} on 7 February to a high value of 15.00 mg m^{-3} on 12 September. The total phytoplankton active chlorophyll *a* values ranged from a low of 0.90 mg m^{-3} on 17 January to a high value of 22.50 mg m^{-3} on 13 June.

Throughout the study, the nanophytoplankton size fraction contributed

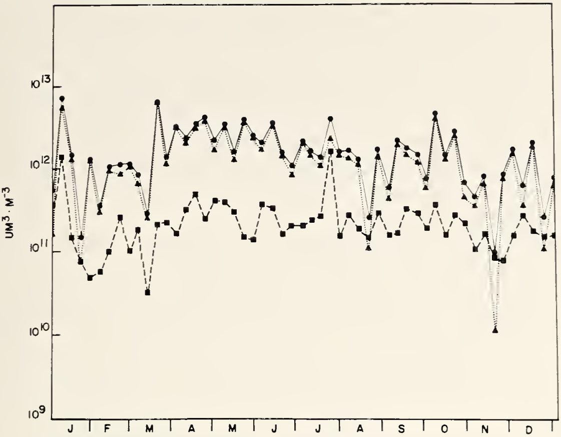

FIG. 10. Total phytoplankton biomass. Total (circles), Diatoms (triangles), flagellates (squares).

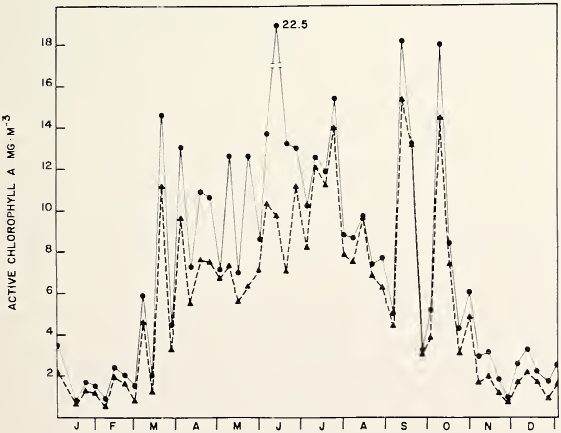

FIG. 11. Active Chlorophyll *a*. Total (circles and solid line); nano (triangles and dashed line).

from 50.0% to 99.7%, with an average of 78.0%, of the active chlorophyll *a*.

DISCUSSION—It has long been appreciated that concurrent with changes in cell density with time, the species composition must also change. Species succession has occurred at high latitudes (Hart, 1934; Digby, 1953; Hsiao et al., 1977), middle latitudes (Lillick, 1940; Conover, 1956; Staker, and Bruno, 1978) and at low latitudes (Riley, 1957; Hulburt et al., 1960). Usually 1 or just a few species are markedly abundant at any one time, and the dominant forms change during the year.

Margalef (1958) attempted to summarize the general pattern of phytoplankton succession. In Margalef's proposed successional scheme, there would exist 3 phases, starting with the spring bloom. The initial phase in the spring would be comprised of small diatoms capable of rapid division. The second phase would consist of medium-sized diatoms with a moderate division rate. The third phase would consist of larger cells with an increased percentage of motile flagellates (dinoflagellates) with a lower rate of cell division.

The general successional pattern we observed follows Margalef's proposed scheme to a certain extent. The initial burst of growth in the spring was characterized by elevated cell densities, increased active chlorophyll *a* values, and relatively small cell sizes. Following the initial spring growth period, there was a general decrease in cell numbers and an increase in mean cell size. This could correspond to the second phase of Margalef's scheme. Increased numbers of dinoflagellates and a further increase in mean cell size in the late summer and fall would correspond to the third phase of Margalef's proposed scheme.

The general species succession we observed parallels successional patterns reported in other estuarine studies. The dominant diatom species in terms of numbers and biomass was *Skeletonema costatum*. It reached the highest cell densities observed during the study of 2.54×10^{10} cells m^{-3} on 13 June. *Skeletonema costatum* at times comprised as much as 99.6% of the total biomass. The highest concentrations of active chlorophyll *a*, nitrate, nitrite, ammonia and orthophosphate observed also occurred on this date. *Skeletonema costatum* has been observed as the dominant species in other North American estuaries by Riley (1952, Block Island Sound), Conover (1956, Long Island Sound), Smayda (1957, Narragansett Bay), Patten et al. (1963, Chesapeake Bay), Hopkins (1966, St. Andrews Bay), and Turner and Hopkins (1974, Tampa Bay).

Most total phytoplankton cell density fluctuations (Fig. 7) were due to variations in the diatom cell densities. The flagellate cell densities ranged over an order of magnitude during the year's cycle, whereas the diatom cell densities ranged over nearly 3 orders of magnitude. This tendency toward relatively stable flagellate cell densities and a highly variable diatom assemblage has also been observed by Hallegraeff (1981) off Australia.

The initial phytoplankton pulse observed in the spring was comprised mainly of relatively small, chain-forming diatoms of the genera *Chaetoceros*, *Nitzschia*, *Skeletonema* and *Thalassiosira*. Other investigators (Mulford, 1972; Conover, 1956; Throndsen, 1978) have reported a similar species composition during the initial spring bloom.

Following the initial spring pulse, the relative number of diatoms decreased, accompanied by a slight increase in the number of flagellates and the appearance of increased numbers of dinoflagellates. The diatom genera, in order of importance at that time, were *Thalassiosira*, *Nitzschia* and *Skeletonema*.

During the late summer-fall season (12 September-10 October), there occurred a second period of increased cell numbers (Fig. 7), increased active chlorophyll *a* values and elevated nutrient concentrations. The most important organisms during this time were *Chaetoceros neogracile*, flagellates, *Thalassiosira nordenskioeldii*, *Skeletonema costatum* and *Paralia sulcata*. This period of increased standing stock along with another period (6 to 27 June) exhibiting similar properties would appear to be related to an irregular, man-induced enrichment phenomenon.

The region surrounding the Indian River contains an extensive canal and floodgate flood control system. This system is maintained by the South Florida Flood Control District (SFFCD). During periods of low rainfall, when the floodgates are kept closed, large quantities of nutrients and other compounds are carried into the flood control canals from surrounding citrus groves, cattle ranches, farms, etc. Nutrient and other chemical concentrations continue to build up until heavy rainfall necessitates opening the floodgates to release water from the system (pers. comm. SFFCD). The high nutrient levels introduced into the Indian River have the potential to greatly influence the river chemistry. During 6 to 27 June, nitrogen levels were extremely high. This period had the highest active chlorophyll *a* values (22.5 mg m^{-3}) and the highest cell density (3.56×10^{10} cells m^{-3}) observed. The highest nutrient levels of the year also occurred at this time. Orthophosphate levels reached 5.64 μM. Ammonia concentrations reached 31.05 μM, nitrate 81.93 μM, and nitrite 1.72 μM, for a total nitrogen concentration of 114.7 μM on 6 June.

This pattern of increased nutrient concentrations leading to increased standing stock was present throughout the summer. A comparison of the orthophosphate-nitrogen curves (Fig. 4) and the net phytoplankton abundance curve (Fig. 6) revealed a positive relationship between increased nutrients and net phytoplankton cell numbers. The net phytoplankton showed a better agreement than did the total phytoplankton collection due to its complete domination by a highly variable diatom assemblage. Diatoms have been reported to respond more rapidly to environmental change than flagellates (Hallagraeff, 1981). This fact coupled with the net collections' ability to detect the rate species might be the reason the net collection showed a better relationship with the nutrients than did the total phytoplankton collections.

This type of artificial enrichment mechanism as a result of increased rainfall has a great potential for alteration of both the biotic and chemical components of the aquatic environment. In addition to nutrient enrichment, the influx of fresh water into the Indian River with its restricted communication with the open ocean, results in large salinity variations. From 6 to 27 June, the salinity dropped from 34 to 24 °/₀₀ and from 12 September to 10 October, the salinity dropped from 34 to 23 °/₀₀.

The highest active chlorophyll *a* and cell density values were observed during these 2 periods of increased rainfall and subsequent water release from the SFFCD. Also, the lowest mean cell volumes and the lowest salinities were observed during these 2 periods.

The total phytoplankton cell densities for this study were compared with similar studies conducted in North American estuaries (Table 3). The yearly mean cell density of 1.38 x 10^{10} cells m^{-3} compared well with the higher cell densities reported elsewhere. These higher values may be partially explained by 2 mitigating factors. The first was the use of an inverted microscope which made possible the enumeration of extremely small (< 2 μm) organisms that may have been overlooked by some investigators. The second factor was that of abundant nutrient availability.

TABLE 3. Mean cell density values for other estuaries. Densities shown in mean cell density x 10^{-6} cells $liter^{-1}$.

Area studied	Reference	Density	Period
Tilsbury Pond, MA	Hulbert, 1956	3.35	All seasons
Long Island Sound	Conover, 1956	2.43	All seasons
Narragansett Bay	Pratt, 1959	5.31	All seasons
Mississippi Delta	Thomas and Simmons, 1960	3.57	Fall, Feb., May
St. Andrews Bay, FL	Hopkins, 1966	0.85	All seasons
Lower Chesapeake Bay	Patten et al., 1963	1.88	All seasons
Beaufort Channel, NC	Williams and Murdoch, 1966	2.00	All seasons
Tampa Bay	Turner and Hopkins, 1974	1.45	All seasons
Long Island Sound	Staker and Bruno, 1978	0.20	All seasons
Gulf of California	Gilmartin and Revelante, 1978	13.26	All seasons
Indian River, FL	Present study	13.80	All seasons

Nutrient values for the Indian River and for other North American estuarine studies are in Table 4. The values observed were amongst the higher levels for estuarine values. One exception is the extremely high PO_4-P value reported by Turner and Hopkins (1974) for Tampa Bay. This was presumably due to extensive surface deposits of phosphate found in the Tampa Bay drainage basin.

TABLE 4. Estuarine Studies: nutrient values, concentrations are micromolar.

Area studied	Reference	NO_3-N	PO_4-P	Period
Narragansett Bay	Smayda, 1957		1.25	All seasons
Chesapeake Bay	Patten et al., 1963	1.17	0.27	All seasons
Apalachee Bay, FL	Donnelly et al., 1966	1.80	0.48	All seasons
Anclote River, FL	Humm et al., 1972	1.53	3.26	October
Tampa Bay	Turner and Hopkins, 1974	2.31	29.16	All seasons
Gulf of California	Gilmartin and Revelante, 1978	0.85	1.25	All seasons
Indian River, FL	Present study	9.24	1.79	All seasons

Total phytoplankton biomass (Fig. 10) over the year was relatively stable. The total phytoplankton biomass ranged from one exceptionally low value of 9.63×10^3 μm^3 m^{-3} on 21 November to a high value of 7.18×10^{12} μm^3 m^{-3} on 10 January with a yearly mean of 1.83×10^{12} μm^3 m^{-3}. Most variation was considered due to fluctuations in the diatom assemblage.

The net phytoplankton, due to its virtually complete domination by diatoms, showed expected high variability (Hallegraeff 1981). This accounts for the range of biomass for the net phytoplankton collection (Fig. 8) extending from 3.18×10^9 μm^3 m^{-3} on 11 July to a high value of 1.04×10^{12} μm^3 m^{-3} on 28 November. The mean net phytoplankton biomass value for the year was 1.71×10^{11} μm^3 m^{-3}.

Considered over the entire study year, the average volume of a cell from the total phytoplankton was 132.6 μm^3. The average size of a cell from the net phytoplankton collection was 1730.8 μm^3.

Chlorophyll *a* concentrations observed in our study are in the upper range of chlorophyll *a* values reported for other estuaries (Table 5). The yearly mean chlorophyll *a* value of 10.69 mg m^{-3} is relatively high; the low value of 1.64 mg m^{-3} occurred on 7 February and the high value of 27.32 mg m^{-3} occurred on 13 June.

CONCLUSIONS — The average total phytoplankton cell density for the year was 1.38×10^{10} cells m^{-3}, and the average net phytoplankton cell density was 9.88×10^7 cells m^{-3}. The mean chlorophyll *a* value for the year was 10.69 mg m^{-3} for the total phytoplankton and 3.42 mg m^{-3} for the net phytoplankton.

The portion of the river studied was characterized by high nutrient concentrations. The yearly mean values for total nitrogen, orthophosphate and silicate were 9.24 μM, 1.79 μM and 53.67 μM, respectively.

Most observed biological standing stock belonged to the phytoplankton size fraction passing through the 20 μm mesh net used in this study. The nanophytoplankton accounted for 99.3% of the numbers, 90.7% of the biomass and 78.0% of the active chlorophyll *a* observed throughout the year long study. The general factors that seem to moderate phytoplankton growth in the Indian River appear to be simply water temperature and solar insolation.

TABLE 5. Chlorophyll *a* plus phaeopigments for other estuaries where Ch1A is in units of mg m^{-3}.

Area Studied	Reference	Chl-A	Period
Alligator Harbor, FL	Marshall, 1956	4.83	All seasons
Long Island Sound	Conover, 1956	6.14	All seasons
Sapelo & Doboy Sounds	Ragotzkie, 1959	11.70	Feb., May, July
Lower Chesapeake Bay	Patten et al., 1963	6.15	All seasons
St. Andrews Bay, FL	Hopkins, 1966	2.13	All seasons
Beaufort Channel, NC	Williams and Murdoch, 1966	4.40	All seasons
Tampa Bay	Turner and Hopkins, 1974	16.43	All seasons
Long Island Sound	Staker and Bruno, 1978	3.00	All seasons
Gulf of California	Gilmartin and Revelante, 1978	4.66	All seasons
Indian River, FL	Present study	10.69	All seasons

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Academy Symposium

PHYSICAL AND HYDRAULIC ANALYSIS OF THE ST. LUCIE INLET IMPROVEMENT PROJECT PRIOR TO AND DURING CONSTRUCTION

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ABSTRACT: *The St. Lucie Inlet offers a unique opportunity to study the dynamic response of a coastal tidal inlet to the construction of an improvement project. A history of the St. Lucie Inlet has been assembled, and aerial photography is being flown throughout the project construction. Hydraulic measurements obtained prior to and during project construction document the original inlet conditions, and analysis of the inlet stability indicates that the St. Lucie Inlet was hydraulically unstable. Construction of the improvement project is nearing completion. A period of readjustment will follow, with the natural forces establishing equilibrium inlet and shoreline configurations.*

ST. LUCIE INLET is undergoing a transformation. Man is building solid, fixed structures and performing dredging operations to control the configuration and hydraulic characteristics of this man-made tidal inlet. Throughout its history, St. Lucie Inlet has been a dangerous inlet, where many boats and human lives have been lost. Frequent dredging of the inlet has been required to keep it open for navigation.

Located at the southernmost end of the Indian River lagoon, the St. Lucie Inlet connects the complex estuarine systems of the Indian River, St. Lucie River, and Intracoastal Waterway with the Atlantic Ocean (Fig. 1). A barrier reef lies immediately offshore of the barrier island at this location. The tide at the inlet is principally semidiurnal, with a mean tidal range of 0.8 m and mean spring range of 0.9 m. The predominant littoral drift is from north to south, strongest during the winters, and with seasonal reversals.

No inlet existed prior to the cut through the narrow barrier island by local residents in 1892. Following this initial cut, the inlet widened naturally due to strong currents. In 1916, dredging of the inlet was attempted under a Federal project, but rapid shoaling of the dredged portion of the channel resulted in the abandonment of this project. Between 1926 and 1929, local interests constructed the 1,000-m north jetty and dredged a channel from the ocean to the entrance of the Manatee Pocket. In 1945 the Federal project was modified to provide a channel 3 m deep and 60 m wide across the offshore bar and reef. This improvement was completed in 1948.

In 1962, a severe storm caused a breakthrough in the barrier island (Jupiter Island) at Peck Lake, about 6 km south of St. Lucie Inlet. This new inlet became the preferred inlet during rough weather, due to the hazardous

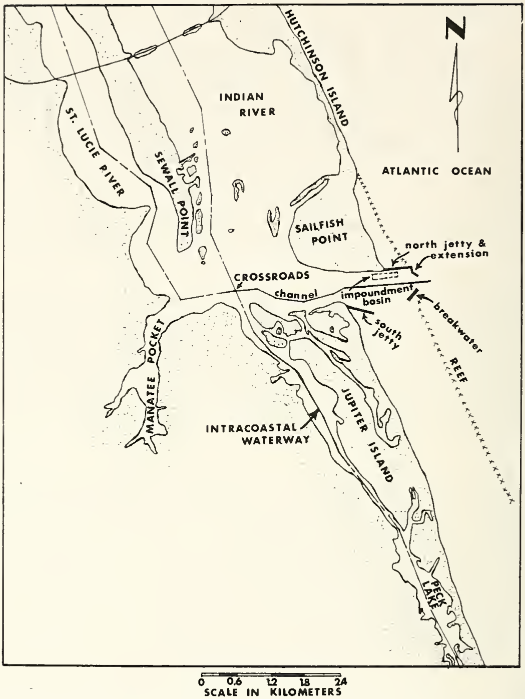

FIG. 1. The St. Lucie Inlet Improvement Project, located in Martin County, Florida.

conditions in St. Lucie Inlet and the protection provided by the offshore reefs at the Peck Lake Inlet. The Peck Lake Inlet was closed by the Corps of Engineers in 1963 to remedy the shoaling and tidal currents in the Intracoastal Waterway resulting from the new inlet.

Emergency dredging of the St. Lucie Inlet entrance was performed by the Corps of Engineers in January 1965. The Federal project was further modified in 1966 to provide for Federal maintenance of a channel 2 m deep and 30 m wide from the authorized bar channel to the Intracoastal Waterway. Since this date, periodic maintenance dredging of the navigation channel, primarily in the bar and reef cut, has been performed.

I discuss the status of the St. Lucie Inlet as of November 1981. Data and analysis performed prior to and during construction of the improvement project, scheduled for completion in 1982, are presented.

IMPROVEMENT PROJECT DESCRIPTION — St. Lucie Inlet Improvement Project design incorporates the concept of a "weir-jetty", in which sand from the littoral drift passes over a section of the jetty and is trapped in an "impoundment basin" (Fig. 1). The 1927 north jetty is utilized for the weir section, allowing sand to pass over and through it, as it has for years. A north jetty extension and a detached breakwater have been added to reduce the wave action inside the inlet. This enhances the navigability of the inlet and provides calm waters for periodic dredging operations of the impoundment basin. Sand dredged during the project construction and periodic maintenance dredging of the impoundment basin will be used to nourish the beaches south of the inlet.

Another feature of the improvement project is a south jetty which extends southeasterly from the north end of Jupiter Island. The jetty is designed to help stabilize the beaches to the south, preventing sand from entering the inlet during flood flow or when waves arrive from the southeast. The south jetty also cuts off a natural tidal current channel that runs south from the inlet inside the reef, diverting this flow in a more easterly direction.

METHODOLOGY—To study the effects of the St. Lucie Inlet Improvement Project, a preconstruction monitoring study was performed under contract with the Army Corps of Engineers (Harris, 1980). Hydraulic measurements, including tidal elevations and current velocities, and a survey of the inlet throat cross section were obtained. Tide data for the ocean were recorded by a tide gage installed north of the inlet and collaborated with predicted tides from the National Ocean Survey Tide Tables. Tide data for the bay area were collected from the area where the Indian River and St. Lucie River intersect, known as the "Crossroads". Recording current meters were installed at the Crossroads area, inlet throat cross section, navigation channel reef cut, and immediately north of the north jetty. To analyze the current regime, dye packets were placed in the inlet area, with flood and ebb flows documented by aerial photography. A repeat of this monitoring study is anticipated, following the completion of the project construction.

The data from the preconstruction monitoring study and subsequent data collected by the author have been used to analyze the hydraulic parameters and stability of the St. Lucie Inlet. The methods of analysis proposed by Keulegan (1967), O'Brien and Dean (1972), and summarized by Mehta (1975) were employed. The analysis utilizes a "repletion coefficient", which indicates the relative efficiency of inlet flushing. Results from the analysis are summarized in Table 1, and compare well with values measured in the field.

The study of St. Lucie Inlet's hydraulic parameters points out the complexity of the interior bay system. The hydraulic analysis utilized in this study assumes the water level rises and falls uniformly and equally throughout the bay area, while in reality, the tidal effect decreases with distance from the inlet. Meteorological conditions, especially wind, also play a very important role in estuary hydrodynamics. The numerical results of the hydraulic analysis are therefore more indicative of an order of magnitude accuracy, varying with local effects.

To document further the effects of the improvement project, a history of the St. Lucie Inlet has been assembled from nautical charts, hydrographic surveys, and aerial photographs. Aerial photographs were taken throughout the project construction, and measurements of the hydraulic parameters are being repeated. This ongoing study is being performed by the author with the assistance of the Florida Oceanographic Society.

RESULTS—Charts and maps prior to the initial cut in 1892 show a relatively straight shoreline in the vicinity of St. Lucie Inlet, with occasional rock outcroppings. Following the initial cut, the inlet widened, eroding the barrier islands and forming interior shoals. A north jetty was constructed in 1927 to stabilize the north shoreline, resulting in seaward accretion north of the jetty almost out to the original shoreline location. South of the inlet, the coast has continued to erode. The barrier reef in Fig. 1 indicates the original location of the coastline.

TABLE 1. Results of hydraulic analysis. Bay data refer to data from the Crossroads area. Time lags are from the ocean tidal elevation to the Crossroads tidal elevation. Slack water refers to slack water in the inlet.

Measured Hydraulic Parameters:	
Ocean spring tidal range:	1.0 m
Bay spring tidal range:	0.4 m
Average phase lag in tidal elevation:	1.75 hrs.
Inlet throat cross section area:	1400 m^2
Inlet throat average depth:	2.5 m
Inlet throat maximum current velocity:	90 cm/sec
Average phase lag of slack water after HW & LW in ocean:	2.75 hrs.
Average spring tidal prism:	1.7×10^7 m^3
Hydraulic Parameters from Keulegan Analysis:	
Repletion coefficient:	K = 0.43
Bay spring tidal range:	0.5 m
Average phase lag in tidal elevation:	2.0 hrs.
Inlet throat maximum current velocity:	85 cm/sec
Spring tidal prism:	1.6×10^7 m^3

Since the 1930s the configuration of the St. Lucie Inlet has changed little. A cut in the offshore bar and reef was completed in 1948 to improve the navigation channel, and frequent dredging of the inlet has been required to maintain a navigable channel. The spoil material from dredging operations was placed in a disposal area immediately south of the navigation channel, creating a large shoal in the area that is now located between the south jetty and detached breakwater.

The dye study showed that before the present project, the tidal current of St. Lucie Inlet was divided into 2 main channels: the navigation channel extending eastward from the inlet, and the south channel which extended southeasterly inside the disposal area and barrier reef. The south channel was used by smaller boats to take advantage of the calmer waters inside the reef. Flood flow, which occurs during higher water levels in the ocean, was more distributed over the inlet throat cross section, while ebb flow, which occurs during lower water levels, was more confined to the 2 main channels, favoring the south channel.

Inside the inlet, the tidal flow was again divided. During flood flow, part of the flow was diverted northward around Sailfish Point (previously known as Seminole Shores), bringing clear ocean water to an area known as the “Sun Parlor”. The remainder of the flow traveled westward to the Crossroads area. During ebb flow, the more turbid water flowed from the Indian River, St. Lucie River, and Intracoastal Waterway south of the Crossroads, and could be traced as a plume extending out into the ocean. Generally, no ebb flow traversed the Sun Parlor area, allowing the clear ocean water to remain (this phenomena is responsible for the area’s name).

The most direct effect of the improvement project on the tidal hydraulics is the blockage of the south channel by the construction of the south jetty. This tidal flow is now diverted easterly, enhancing the flow in the navigation channel. This increased flow could help to maintain the navigation channel.

The stability of the St. Lucie Inlet against closure can be determined from the results of the data analysis. O'Brien and Dean (1972) proposed that the hydraulics of an inlet-bay system determine a critical cross sectional area, A_c^*. If the actual throat cross sectional area is greater than the critical throat cross sectional area, $A_c > A_c^*$, the inlet is stable. Treating the inlet throat cross sectional area and hydraulic radius as variables, and the tidal period, ocean amplitude, bay area, and inlet length as constants, a plot of the maximum throat velocity versus throat cross sectional area is obtained (Fig. 2).

The critical cross sectional area is found to be approximately 2500 m^2 with an associated maximum throat velocity of almost 100 cm s^{-1}. Because the inlet throat cross sectional area is less than the critical cross sectional area, $A_c < A_c^*$, St. Lucie Inlet remains hydraulically unstable prior to completion of the improvement project. A reduction in the cross sectional area

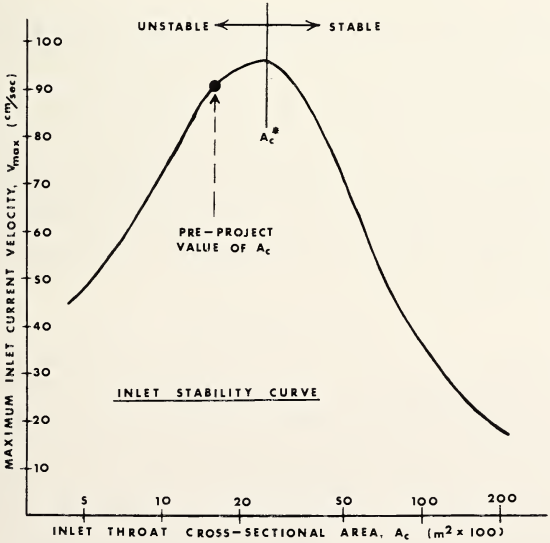

FIG. 2. Hydraulic analysis of the stability of the St. Lucie Inlet prior to the improvement project.

due to shoaling would mean a corresponding reduction in the maximum throat velocity, thereby enhancing the possibility of further shoaling.

CONCLUSIONS — I present the status of the St. Lucie Inlet as of November 1981. Construction is nearly completed, with the structures in place and dredging operations scheduled for completion in early 1982.

A large shoal has continued to exist between the south jetty and the detached breakwater in the former disposal site of inlet maintenance dredging. Tidal flow through this area is therefore very limited. Should a major current develop between the south jetty and detached breakwater, an extension of the south jetty could become necessary to redirect major tidal flow through the navigation channel.

Investigations thus far show that no appreciable change in tidal range inside the inlet has occurred due to project construction. This indicates that the tidal prism has not been reduced. Tidal flow through the navigation channel and maximum tidal current velocity have increased, while the inlet throat cross sectional area has decreased. The analysis of inlet stability indicates that St. Lucie Inlet was unstable prior to the recent construction, and that an increase in throat cross sectional area is needed for stability. The completion of the improvement project, primarily the completion of the dredging operations, may greatly alter the final inlet hydraulics and enhance the inlet's stability.

Completion of the St. Lucie Inlet Improvement Project will be followed by a period of readjustment, with the natural forces of the tide, currents, and waves redistributing the sediments and establishing equilibrium inlet and shoreline configurations. Monitoring of the inlet during this period is essential, both to document the performance of the project, and to determine the project's affects on the surrounding waters and shorelines.

ACKNOWLEDGMENTS — The facilities of the Florida Oceanographic Society in Stuart were utilized for coordination of the field work, with Mark Perry providing boat services and assisting in data collection. Computer data processing and field operations assistance were furnished by Mel Walker of KMW Digital Systems. Chris Perry, professional photographer, supplied historical aerial photography. Ken Humiston of Coastal Technologies in Naples, Florida, provided diving assistance in instrument installation and retrieval. The aircraft flown for aerial photography was piloted by Ken Harris.

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Academy Symposium

PORE WATER CHEMISTRY OF AN OVERWASH MANGROVE ISLAND

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Abstract: *Variations in concentrations of pore water constituents in sediments beneath mangrove communities in the Indian River lagoon are related to the physiology of the mangroves and tidal inundation regimes of the sediments. Both* Rhizophora mangle *and* Avicennia germinans *increase concentrations of sulfate and chloride in pore water by partial exclusion of salts from water taken up by transpiration. Sulfate is excluded by the plants to a greater extent than chloride, elevating pore water sulfate: chlorinity ratios. Changes in pore water sulfide, iron, phosphate, and nitrate concentrations appear to be coupled to seasonal and shorter term variations in tidal inundation frequency. Differences in sulfide concentrations of the 2 zones suggest that heterotrophic microbial activity is greater in* Rhizophora *sediments than in* Avicennia *sediments. Total rates of microbial metabolism may be similar in both zones if microorganisms in* Avicennia *sediments utilize a wider range of terminal electron acceptors than are available in* Rhizophora *sediments. Large variations in the dissolved Fe concentrations of* Avicennia *pore water may mean that iron serves as an important terminal electron acceptor for heterotrophic microorganisms.*

Interpretive geochemical models developed for deepwater anoxic marine sediments do not apply well to salt marsh sediments. While many of the same microbial processes occur in both environments, the rates and relative importance of particular transformations are modified in the marsh sediments by the presence of rooted macrophytes, intermittent exposure to atmospheric oxygen, and variability of the physical environment (Howarth, 1979; Howarth and Teal, 1979). Rates of heterotrophic microbial activity in marsh sediments may be considerably enhanced by the high rates of primary production, while the input of "new" organic matter below the sediment surface by the turnover of roots (Valiela et al., 1976; Hackney and de la Cruz, 1980) or the leakage of dissolved organic compounds from live roots (Mendelssohn et al., 1981) may alter the vertical segregation of heterotrophic processes. The diffusion of oxygen from the roots of macrophytes to the surrounding sediments may alter the redox environment of the sediments (Carlson, 1980; Howes et al., 1981), and the selective uptake of ions by the macrophytes may affect the composition of pore waters (McGovern et al., 1979). In some marshes with relatively permeable peat, considerable quantities of pore water may drain from the marsh at low tide to be replaced on the flood tide (Howarth et al., in press). Transpiration of the macrophytes may also result in rapid turnover of the pore water within the sediments (Carlson, 1980). Seasonal variations in tidal inundation frequency may alter the redox environment of sediments, while changes in salinity of the overlying water may affect diffusive fluxes and concentrations of ions in pore water.

Mangroves are important in the trophic dynamics of subtropical estuaries (Odum and Heald, 1972) and may be important components of nutrient cycles as well, but little work has been done on the sediment chemistry of mangrove swamps. As a first step toward evaluating the role of mangroves in estuarine nutrient cycles and determining the effects of the mangroves themselves as well as environmental factors on sediment chemistry, we have studied the pore water chemistry of an overwash mangrove island in the Indian River lagoon for the past year.

STUDY AREA — Mangroves are present within the Indian River both as fringing forests along the shoreline and as the dominant vegetation of overwash islands within the lagoon. Overwash mangrove forests, as defined by Lugo and Snedaker (1974), are typically islands or small peninsulas within bays or estuaries which are dominated by the red mangrove, *Rhizophora mangle*, and are frequently inundated by tides. We chose to study an island forest because we wanted to reduce groundwater influences on pore water chemistry, and because fringing mangrove forests have been extensively altered by construction and mosquito control impoundments. The island studied has a fringe zone (10-50 m wide) dominated by *Rhizophora mangle* and a larger central (80-120 m wide) zone which has a canopy of black mangrove, *Avicennia germinans*, and a subcanopy of *Rhizophora*. The elevation difference between the seaward fringe of the *Rhizophora* and the flat central portion of the island is only 20 cm. The lower 10 cm elevation is occupied almost solely by *Rhizophora*, and *Avicennia* is completely limited to the upper 10 cm of the elevation range.

METHODS — Pore water samples were collected under an argon atmosphere in porous Teflon samplers (Zimmermann et al., 1978). The samplers were left *in situ* at depths of 10, 20, 30, 40 and 50 cm in each zone, and samples were collected at intervals varying from 1 to 6 wk during 1981. Eh and pH were determined in the field using an Orion 401 field meter and an anaerobic flow-through sample cell. Electrodes were calibrated in the field using 2 buffer solutions (for pH) and Zobell's (1946) solution for Eh. Sulfide samples were collected in syringes, preserved in the field with SAOB (sulfide antioxidant buffer), and analyzed using a sulfide specific ion electrode (Orion Res., Inc., 1975). The electrode was calibrated for sulfide concentrations ranging from 5 μM to 5 mM by dilution of a primary sulfide standard solution made up in SAOB. The exact molarity of the primary standard ranged from 5 to 10 mM and was determined by potentiometric titration with lead perchlorate, using the sulfide electrode to determine the endpoint. Chloride was determined titrimetrically (APHA, 1975), and sulfate was determined by a modification (Bricker and Montgomery, pers. comm.) of the automated turbidimetric method of Santiago et al. (1974). Iron was determined using the Ferrozine procedure (Stookey, 1970), and nutrients were determined by automated techniques (Montgomery et al., 1979).

The frequency and duration of tidal inundation of the island were determined by relating tidal heights measured at the study site to a continuous record of water levels measured at Link Port, 3.8 km north of the island. Local mean sea level (LMSL) was calculated as the mean of 208 high and low water elevations (4 values of alternating high and low tides for each of 52 da measured weekly between 5 October 1980 and 6 October 1981).

RESULTS — Separation of the effects of temperature, rainfall, and tidal inundation on pore water chemistry is complicated because their timing is similar (Fig. 1). Water temperature peaked in August at 29°C, while this year's greatest rainfall (33 cm) occurred during the passage of Tropical Storm Dennis on 14-17 August. Rainfall during the spring and early summer was considerably lower than average.

The seaward limit of *Rhizophora* prop roots was located quite uniformly around the perimeter of the island at an elevation of −1 cm relative to local mean sea level (LMSL), while the lower limit of *Avicennia* was located at an elevation of +9 cm above LMSL. The slight difference (10-15 cm) in elevation between the 2 zones of the island resulted in distinctly different tidal inundation regimes (Fig. 1). The *Rhizophora* fringe was flooded at least 3 times a week throughout the year except for 1 wk in early March and 3 wk in June. The *Avicennia* zone was flooded only twice during April, 4 times in July, and not at all for most of the month of June. During the fall and winter, flooding of the entire island occurred frequently, and there were periods when the island was continuously inundated for up to 24 hr at one time. The total number of tidal inundations of the *Avicennia* zone from October 1980 to October 1981 was 255 (35% of all high tides), while the *Rhizophora* zone was flooded 534 times (73% of all high tides). Chapman (1944) reports similar inundation frequencies for the *Rhizophora* and *Avicennia* zones of a fringing mangrove forest in Jamaica.

Pore water chloride (Fig. 2) and sulfate (Fig. 3) concentrations of both zones of the island were elevated over concentrations in the overlying water throughout the year. Enrichment was greatest at mid-depths during July and August, and was greater in the *Avicennia* zone than in the *Rhizophora* sediments. Lowered salinities in the flooding tidal water and the resumption of frequent inundation of the island in September reduced concentrations at most depths either by diffusion or mass flux of pore water.

Sulfate: chlorinity ratios in pore water normalized to seawater values (indicated as 1.0 in Fig. 4) showed that sulfate was concentrated in the pore water of both zones to a greater degree than chloride, indicating that some mechanism other than evaporation was responsible for the enrichment. The extent of the enrichment was greater in the sediments of the *Avicennia* zone. Selective uptake of chloride by mangroves in transpiration was established as the mechanism responsible when the sulfate:chlorinity ratios of canopy throughfall samples (Table 1) were found to be enriched in chloride. Sulfate:chlorinity ratios in the overlying water were also different from seawater indicating that biological activity may be locally important in controlling the surface water chemistry of the Indian River as well as pore water.

Sharp differences were apparent between the sulfide concentrations of the 2 zones. Sulfide values (Fig. 5) were extremely low in the *Avicennia* sediments throughout the year, while the *Rhizophora* sediments had concentrations similar to values reported for seagrass (Montgomery et al., 1979) and temperate marsh sediments (Carlson, 1980; Howarth et al., in press). Concentrations in both areas were depressed during the summer when inundation was less frequent.

Iron chemistry also showed marked differences between the 2 zones of the island (Fig. 6). High concentrations of dissolved iron were present in the pore water of the *Avicennia* zone during periods of frequent inundation dur-

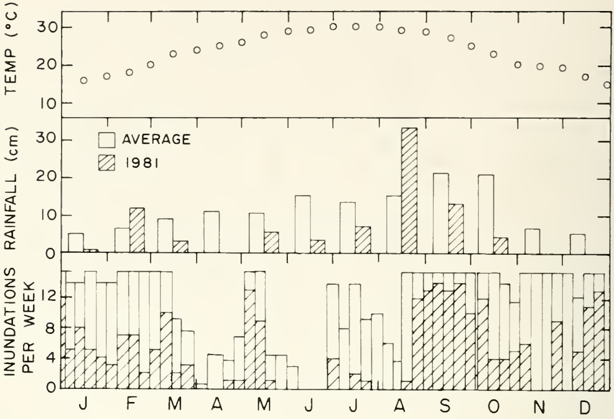

Fig. 1. Seasonal variations of environmental parameters of the study site. Water temperature data from 1976-77, redrawn from Mook (1980), but representative of general seasonal pattern. Rainfall measured in Vero Beach, 10 km N of study site. Inundations per week refer to only those high tides when the entire island was submerged. Open bars represent *Rhizophora* zone, hatched bars represent *Avicennia* inundation frequency.

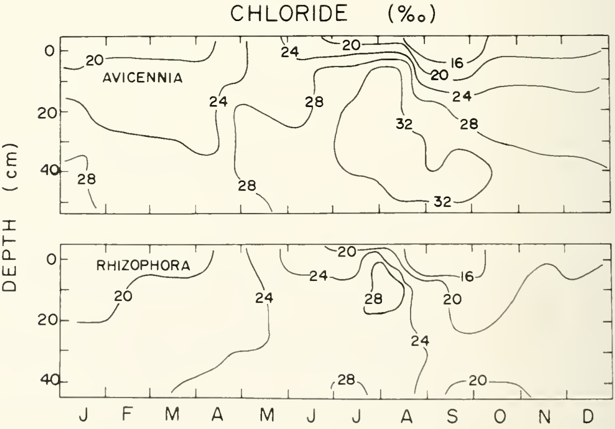

Fig. 2. Pore water chloride concentrations. Data above zero depth in sediments reflect values in surface water of adjacent lagoon.

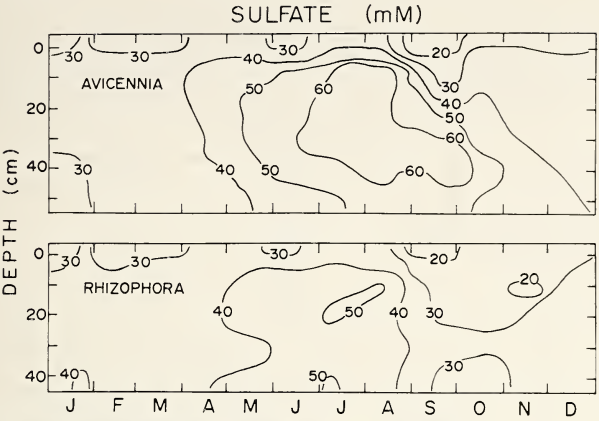

Fig. 3. Sulfate concentrations in pore water of mangrove sediments.

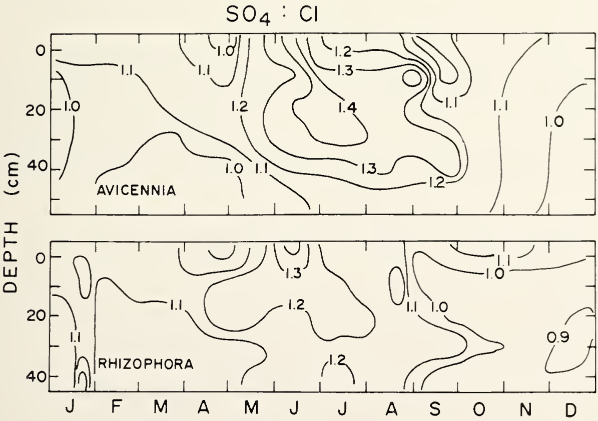

Fig. 4. Sulfate: chlorinity ratios of mangrove sediment pore water. Values are normalized to standard seawater: values exceeding 1.0 indicate selective enrichment of sulfate in pore water.

Table 1. Comparison of sulfate: chlorinity ratios among surface water, pore water, rainfall, and canopy throughfall of the mangrove study site for July-August 1981. Standard seawater of 35 ppt salinity contains approximately 27 mmoles sulfate l^{-1}; and has a molar sulfate: chlorinity ratio of 0.052. Canopy throughfall is rainwater which washes recreted salts off the leaves of both mangrove species before falling into collectors. Rainfall is collected above the forest canopy.

	Sulfate: Chlorinity Ratio		
Water Mass	Molar Ratio	Normalized to Seawater	N
Seawater	0.0515	1.00	4
Mangrove lagoon (Indian River)	0.0589	1.14	4
Rhizophora pore water	0.0581	1.13	14
Avicennia pore water	0.0688	1.34	12
Rainfall	0.1274	2.47	12
Canopy throughfall	0.0087	0.17	19

ing the spring and fall. Concentrations in the upper 20 cm of sediment during the summer were much lower than spring and fall, suggesting that the *Avicennia* sediments become oxidized during the period of infrequent inundation. Iron concentrations in the *Rhizophora* sediments were low throughout the year, but were attributed to iron sulfide precipitation because of high sulfide concentrations.

Phosphate concentrations in the *Avicennia* sediments (Fig. 7) followed the seasonal pattern of dissolved iron, suggesting that phosphorus may move from the particulate to the dissolved phase as the result of reduction and dissolution of iron (III)-phosphorus complexes after the onset of regular inundation in the fall. Elevated phosphate concentrations persisted in the deeper *Avicennia* sediments during the fall when iron concentrations declined, possibly as the result of iron sulfide precipitation. Phosphate concentrations in *Rhizophora* pore water were low for most of the year, but were elevated during the fall.

Pore water ammonia values (Fig. 8) were low in both zones at all times by comparison with other marine sediments, possibly as the result of uptake by the mangroves. The decline of concentrations with depth may indicate that mineralization of surface detritus is an important source of nitrogen for the sediments. Peak concentrations occurred during the summer period in both areas. Nitrate concentrations (< 1 μm) were present in the upper sediments of both zones during the summer.

Discussion—Both mangrove species apparently increase concentrations of sulfate and chloride in pore water by removing water from the sediment for transpiration and partially excluding salts from the water taken up (Scholander et al., 1962). Sulfate is excluded to a greater degree than chloride from the water taken up, elevating the sulfate: chlorinity ratio of the pore water. This effect has been reported for *Spartina alterniflora* (McGovern et al., 1979; Carlson, 1980), but the enrichment observed is greater in mangrove sediments than salt marsh sediments, at least partially because low sulfate reduction rates in mangrove sediments (Carlson et al., unpubl. data) do not offset the transpiration effect. Greater enrichment in

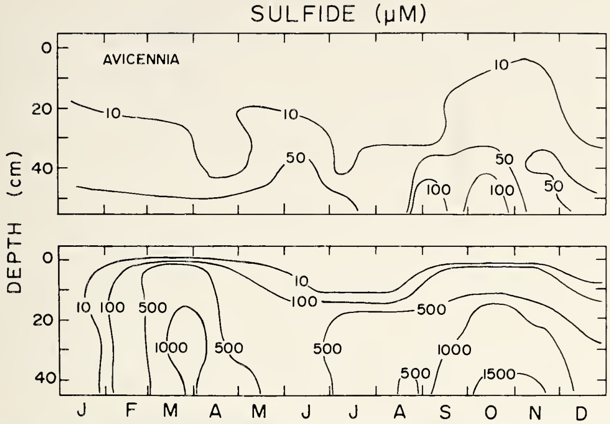

FIG. 5. Dissolved sulfide concentrations in mangrove pore water.

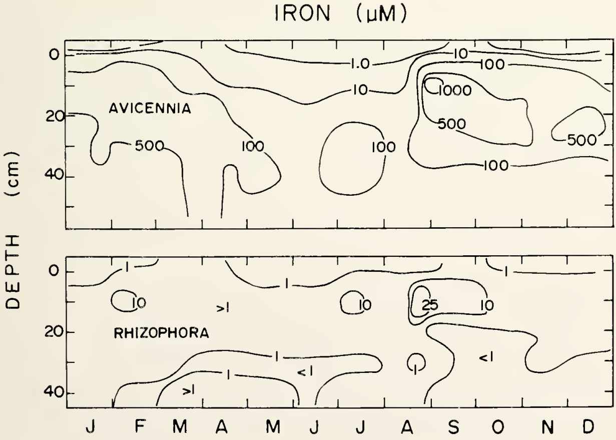

FIG. 6. Dissolved iron concentrations in pore water of mangrove sediments.

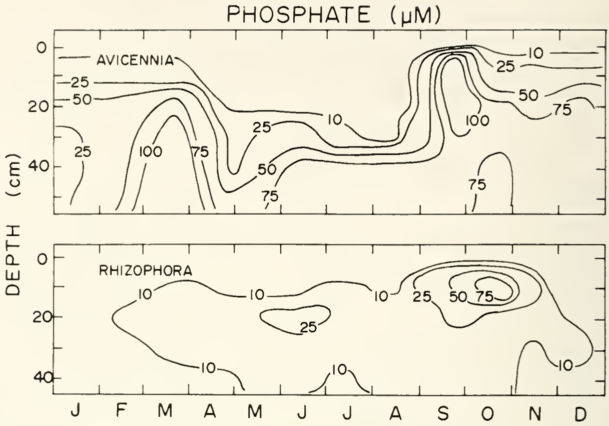

Fig. 7. Phosphate concentrations in mangrove sediment pore water.

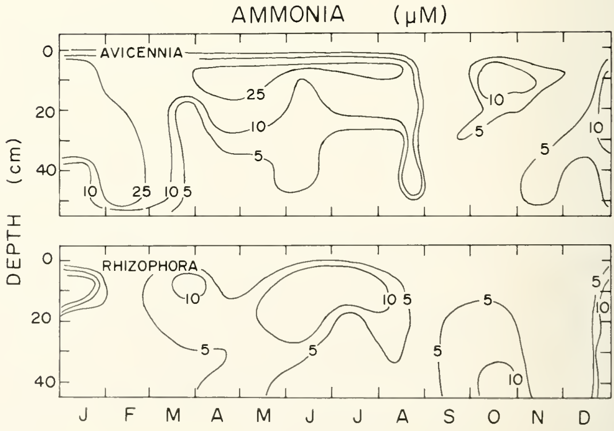

Fig. 8. Ammonia concentrations in pore water of mangrove sediments.

the *Avicennia* zone may be due to species composition: *Avicennia* transpires and secretes salt on its leaves at much higher rates than *Rhizophora* (Scholander et al., 1962). However, more frequent inundation of the *Rhizophora* zone also provides greater opportunity for diffusive exchange and mass flux of pore water.

The effects of root oxygen loss on pore water chemistry could not be discerned from our data. Prop roots of *Rhizophora* and pneumatophores of *Avicennia* are known to provide oxygen from the atmosphere to belowground tissue (Scholander et al., 1955), but leakage of oxygen from mangrove roots to the surrounding sediments was not apparent from the variation of redox-sensitive pore water constituents, nor were any iron precipitates visible on the root surfaces. Oxygen flux rates from *Spartina alterniflora* roots in temperate salt marsh sediments are low (Carlson, 1980), and fluxes from more heavily cutinized mangrove roots might be even lower, reducing any potential effects on pore water chemistry. Furthermore, the consistent lower elevation limits of both species suggest that tidal inundation regimes limit their ability to supply enough oxygen to meet the respiratory demands of belowground tissue.

Levels of other pore water constituents, such as iron and phosphate, appear to be controlled more by inundation frequency than by the physiology of the mangroves. In the absence of large annual inputs of iron and phosphorus to the island system, the large differences in their respective concentrations in the *Rhizophora* and *Avicennia* sediments may result from fluxes of dissolved species from *Rhizophora* sediments to the water of the adjacent lagoon, uptake by *Rhizophora*, or precipitation of mineral phases. Loss of phosphate probably occurs by infiltration of tidal water into the *Rhizophora* sediments which displaces pore water laterally into the lagoon at low tide—a mechanism which has been reported for Sippewissett marsh (Howarth et al., in press). As much of the reducible iron in *Rhizophora* sediments is precipitated as FeS (Carlson et al., unpubl. data), there is no barrier at the sediment-water interface to prevent phosphate loss. Infiltration and drawdown of pore water between tidal flooding episodes is slower in the *Avicennia* sediments than in *Rhizophora* sediments, and low sulfide standing stocks leave most of the reduced iron in pore water, so iron and phosphate are retained to a greater extent in the *Avicennia* sediments, cycling back and forth between the particulate and the dissolved phase as the sediments are alternately oxidized and reduced.

The large pool of reducible iron in the *Avicennia* sediments suggests that it may be an important terminal electron acceptor for heterotrophic microbial metabolism. Ottow and Munch (1981) have demonstrated that iron is reduced in flooded soils by bacteria rather than by end products of microbial metabolism. Patrick and Henderson (1981) also showed that iron reduction was a result of microbial catalysis and that it occurs at Eh values considerably higher than those predicted by thermodynamic equations (Krauskopf, 1957). The upper sediments of the *Avicennia* zone are frequently oxidized during periods of low inundation frequency. When the sediments become saturated again with the onset of regular tidal flooding, bacterial metabolism proceeds as a series of steps (Ponnamperuma, 1972) where oxygen, nitrate, and iron are sequentially utilized as terminal electron acceptors before the initiation of sulfate reduction. While the amount of reducible iron in the sediments is limited, it can be rapidly re-oxidized when the sediments are not inundated.

The low standing stock of dissolved sulfide in the *Avicennia* sediments may be due to the rapid accumulation of iron sulfides, as has been demonstrated elsewhere (Howarth, 1979), or may result from low sulfate reduction rates. The latter explanation is supported by measurements of sulfate reduction rates (Carlson unpubl. data), as well as measurements of total oxidizable sulfur in mangrove sediments of West Africa (Hart, 1959) and New Zealand (Dent, 1980). Both authors found that standing stocks of sulfide were lower in *Avicennia* sediments than in *Rhizophora* sediments, even though the species involved were different from those present here in south Florida. Despite low sulfate reduction rates, total rates of microbial respiration may be similar in the *Avicennia* and the *Rhizophora* sediments, if the microorganisms in the *Avicennia* sediments utilize terminal electron acceptors other than sulfate. The unknown factor influencing microbial metabolism is the input of organic matter from the mangrove roots to the sediments. The species-specific rates of belowground biomass turnover and the susceptibility of mangrove root tissue to anaerobic breakdown may influence pore water chemistry and require further investigation.

CONCLUSIONS—Variations in concentrations of pore water constituents in sediments underlying mangrove communities of the Indian River lagoon are associated with the dominant mangrove species present and differences in tidal inundation regimes of the zones occupied by *Rhizophora mangle* and *Avicennia germinans*. It is not clear whether the 2 mangrove species have different effects on pore water chemistry, or whether their distribution is determined by the same factors which are responsible for observed differences in pore water chemistry.

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SUMMER-SEASON POPULATIONS OF EPIBENTHIC MARINE FISHES IN THE INDIAN RIVER LAGOON SYSTEM, FLORIDA

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ABSTRACT: *Epibenthic marine fish populations were sampled in order to establish quantitative baseline data for use in long-term monitoring of the northern Indian River lagoon system, Florida. Fish samples were taken by trawling monthly at 8 fixed stations from June through September 1979 and 1980. Fifty-seven species representing 29 families were collected. The community was numerically dominated by a very few species.* Anchoa mitchilli *alone accounted for 87% of the 105,853 individuals collected. Abundance, dominance, and species diversity were compared among the 3 lagoon subdivisions—Mosquito Lagoon, Indian River, and Banana River. Greater numbers of fishes were collected in the Indian River, whereas the highest diversity levels were in the Banana River. Although most species were collected in all 3 subareas, inequities occurred in the numbers of individuals taken. For example, Mosquito Lagoon produced significantly more* Micropogonias undulatus *and* Leiostomus xanthurus *than either the Indian or Banana rivers. Significantly more* Syngnathus scovelli *and* Anchoa mitchilli *were collected in Indian River than in Banana River, and Banana River produced significantly more* Lagodon rhomboides *than did Indian River. The only measured environmental parameters that appeared to be significant in determining fish populations were vegetative cover and salinity. An importance value (IV) index, combining relative abundance, relative frequency of capture, and relative size (biomass) per individual, was calculated for each species in the community. Dominance ranking by IV has advantages over dominance ranking by relative abundance alone and is valuable for making comparisons in a long-term monitoring study.*

ESTUARIES and lagoons make up 80 to 90% of the Atlantic and Gulf coasts of the United States. These habitats are among the most productive in the world (Odum, 1961), providing nursery grounds for commercial and sport fish and shellfish as well as fishes and invertebrates with no direct economic importance. It is generally acknowledged that steps must be taken to maintain these highly productive ecosystems. However, in spite of their biological importance, coastal environments in the southeastern U.S. are being developed and industrialized at an accelerating rate. Unfortunately, this "progress" brings with it alteration or destruction of habitats, increased waterway usage, and pollution from chemicals, sediments, and waste. Surveillance of these threatened aquatic systems is necessary to distinguish short-term fluctuations (cyclical or stochastic) from long-term, perhaps irreversible, trends (Hellawell, 1977). Consequently, there is an urgent need for environmental research to establish quantitative base-line data for use in long-term monitoring programs.

One approach for monitoring the "health" of an environmental system is through the study of a species or group of species that reflect the ecological status of the system. Benthic invertebrate species and communities have classically been considered to be the best indicators of environmental perturbations because of their persistence, sedentary habits, and differing tolerances to stress (Wass, 1967). However, groups as divergent as wading birds (herons and their allies) have been used as indicators of habitat quality in coastal environments (Custer and Osborne, 1977).

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The use of fishes as indicators of disturbance in estuarine environments was first promoted by Bechtel and Copeland (1970). They showed that fish diversity was inversely proportional to pollution in Galveston Bay, Texas. Furthermore, diversity indices derived from fish populations were stable enough to permit the development of predictive models (Copeland and Bechtel, 1974). Subsequently, many other studies have used fish population data in the surveillance of estuarine systems (e.g., Dahlberg and Odum, 1970; Dahlberg, 1972; Oviatt and Nixon, 1973; Hillman et al., 1977; Livingston, 1977; Horn, 1980).

Florida's Gulf coastal marine and estuarine fish fauna has received considerable attention during the past 30 yr (Reid, 1954; Kilby, 1955; Joseph and Yerger, 1956; Springer and Woodburn, 1960; Tabb et al., 1962; Gunter and Hall, 1965; Zilberberg, 1966; Wang and Raney, 1970; Livingston, 1976, 1977; Livingston et al., 1974, 1976, 1977; Subrahmanyam and Drake, 1975; and Ogren and Brusher, 1977). In contrast, surprisingly few studies have dealt with the ecology of fishes inhabiting the east coast of Florida, especially the expansive Indian River lagoon system. Published studies of the fish fauna of this lagoonal system have been either qualitative (e.g., Evermann and Bean, 1897; Snelson and Williams, 1981) or semiquantitative (Gilmore, 1977). Lack of appropriate sampling procedures and quantitative results reduce the value of these earlier studies as bases for future comparisons. The only quantitative data that exist for fish populations in the lagoon system are unpublished works by Gilmore (1974, haul seining), Schooley (1977, 1980, seining), and Snelson (1980, trawling). The work we report here is a continuation of the quantitative trawling program initiated by Snelson in 1977. Our results provide the first quantitative data on the summertime epibenthic fish populations in the Indian River estuary.

AREA DESCRIPTION — The Indian River lagoon system extends along the east coast of Florida from Ponce de Leon Inlet (Volusia County) south to St. Lucie Inlet (Martin County), a distance of 220 km. Three interconnected bodies of water, Mosquito Lagoon, Indian River, and Banana River, compose the system. The lagoons are separated from the Atlantic Ocean by narrow barrier beaches except in the north-central region where Cape Canaveral and Merritt Island are wider land masses. Four small inlets, Ponce de Leon, Sebastian, Fort Pierce, and St. Lucie, are the only links between the lagoons and the ocean.

The lagoons vary in width from 8 km in the vicinity of Titusville to 1-2 km in the central and southern regions. Average depth is about 1.5 m and depths greater than 4-5 m are primarily confined to dredged basins and channels of the Intracoastal Waterway. The name "river" applied to 2 of the

3 major basins is a misnomer because there is no consistent flow pattern or gradient. Wind is the primary agent of water movement, and lunar tides are insignificant except near the inlets (Chew, 1956; Schneider et al., 1974; and Gilmore, 1977). Fresh-water runoff is significant only in very localized areas. Waters of the lagoons are mesohaline but salinity varies considerably with rainfall, evaporation, and proximity to ocean inlets.

Extensive beds of rooted seagrasses are prominent in the shoal areas but rarely extend into the deeper, central portions of the lagoons. The dominant seagrass species throughout the system are *Cymodocea filiformis* (= *Syringodium filiforme*) (manatee grass), *Halodule beaudettei* (= *Halodule wrightii*) (shoal grass), and *Thalassia testudinum* (turtle grass). In addition to seagrass, the lagoonal waters are characterized by an extensive macroalgae flora (Eiseman and Benz, 1975). These algae develop attached to the substrate; but after a period of growth, they break free and drift across the bottom on wind-driven currents. Extensive mats of "drift algae" occur throughout the deeper waters of the lagoon system.

Our study area was in the northern portion of the Indian River lagoon system near Merritt Island in northern Brevard County, Florida (Fig. 1).

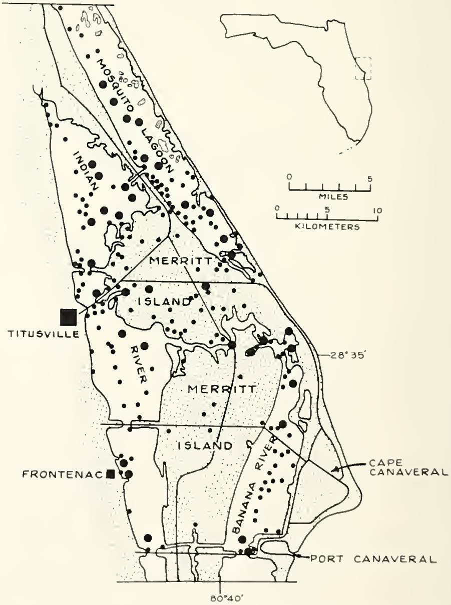

FIG. 1. Map of the northern portion of the Indian River lagoon system, Florida, showing the 3 lagoon basins, important landmarks, and 8 sampling stations employed in this study.

Near the northern end of the study area, the man-made Haulover Canal connects Mosquito Lagoon and Indian River. At the extreme southern end of the study area, the man-made Barge Canal joins Indian River and Banana River. Instead of complete bridges, causeways were constructed to carry traffic across the Indian and Banana rivers. The 6 causeways effectively divide the 2 bodies of water into semi-isolated basins. The Intracoastal Waterway runs through Indian River and the northern half of Mosquito Lagoon. A series of spoil banks and islands parallel the dredged channel. Substantial urban development occurs only in the area of Titusville. Considerable industrial and military development occurs on Merritt Island (J. F. Kennedy Space Center) and Cape Canaveral (Cape Canaveral Air Force Station). Man's most dramatic influence on the lagoons in this area has been extensive shore-line diking to create brackish mosquito-control impoundments. These impoundments have eliminated most *Spartina* marshes native to the area and the lagoons are now bordered by mangroves, primarily *Laguncularia racemosa* and *Avicennia germinans*.

STUDY STATIONS — Fixed-station sampling was used in this study. Because trawling was difficult and ineffective at depths of less than 2 m, sampling was limited to the deeper, central areas of the lagoons and the dredged channels or basins. Furthermore, the extensive accumulation of drift algae made it impossible to pull a trawl in some deep-water areas. Thus, the selection of sampling stations was dictated in part by the sampling gear employed and the nature of the environment. After exploratory trawling, 8 sampling stations were selected that represented "typical" open lagoon habitats and gave broad geographical coverage within the study area.

The study area was naturally divided into 3 subareas or basins: Mosquito Lagoon contained stations 1 and 2, Indian River contained stations 3-6, and Banana River contained stations 7 and 8. Station locations are shown in Fig. 1 and brief descriptions follow.

Station 1: lat. 28°47′00″N, long. 80°46′30″W; Mosquito Lagoon at navigation marker #31; ca. 17.5 km NNE Titusville. Station located in dredged channel of Intracoastal Waterway; average depth 3.8 m; bottom sediment firm sand; drift algae consistently present, seagrasses in shoals east of station.

Station 2: lat. 28°42′30″N, long. 80°42′30″W; Mosquito Lagoon 1 km WNW Turtle Pen Point; ca. 14 km ENE Titusville. Average depth 2.6 m; bottom sediment sand and silt; drift algae and seagrasses rarely observed.

Station 3: lat. 28°43′30″N, long. 80°46′00″W; Indian River between western terminus Haulover Canal and navigation marker #3; ca. 13 km NNE Titusville. Station narrowly confined in dredged channel of Intracoastal Waterway; average depth 3.8 m; bottom sediment firm sand; drift algae consistently abundant.

Station 4: lat. 28°39′00″N, long. 80°48′00″W; Indian River immediately N of railroad causeway; ca. 3 km NNE Titusville. Average depth 3.5 m; bottom sediment firm sand and shell rubble; drift algae always present.

Station 5: lat. 28°37′40″N, long. 80°48′30″W; Indian River between navigation markers #30 and #31, ca. 0.25 km S Hwy. S.R. 406 bridge; at Titusville. Station located in dredged channel of Intracoastal Waterway and adjacent deep areas east and west; average depth 3.9 m; bottom sediment firm sand with small amounts of shell rubble; drift algae variable.

Station 6: lat. 28°25′00″N, long. 80°44′30″W; Indian River between navigation markers #66 and #67; ca. 1 km N Hwy. S.R. 528 bridge; ca. 19.5 km SSE Titusville. Station located in dredged channel of Intracoastal Waterway and adjacent waters east and west; average depth of 3.7 m; bottom sediment firm sand overlain by small amount of silt; drift algae sparse in 1979, more abundant in 1980.

Station 7: lat. 28°32′00″N, long. 80°36′30″W; Banana River between navigation markers #39 and #42, immediately W of Vertical Integration Building on Cape Canaveral Air Force Station; ca. 19 km ESE Titusville. Station narrowly confined to dredged channel; areas to either side shallow, supporting extensive seagrass growth; average depth 3.9 m; bottom sediment firm sand and shell rubble; macroalgae cover consistently sparse.

Station 8: lat. 28°24′30″N, long. 80°38′30″W; Banana River in triangular area between navigation markers #5, #13, and #15, ca. 0.7 km N Hwy. S.R. 528 bridge near western end of Port Canaveral navigation locks; ca. 23 km SSE Titusville. Station located in dredged channel and adjacent waters to the west; average depth 4.2 m; bottom sediment soft silt; drift algae usually sparce.

Methods and Materials

Collecting and Processing—Fishes were sampled monthly from June to September 1979 and 1980. The sampling gear was a 4.9 m semi-balloon otter trawl with 3.2 cm wing mesh and 6.2 mm mesh cod-end innerliner. The trawl was towed from the stern of a power boat at about 4 knots. All trawling was conducted during daylight hours.

Seven sequential tows of 2 min each constituted the sampling procedure at a station. Time between sequential tows ranged from about 3 to 30 min, depending on the catch and weather conditions. All fishes collected in a tow were preserved and returned to the laboratory for processing. Fishes were sorted to species, identified, and enumerated. Larvae, mostly *Anchoa* sp., were excluded from consideration. Specimens were measured to the nearest mm standard length (SL) with vernier dial calipers. All individuals of a species were weighed together on an electronic toploading balance to the nearest 0.1 g after blotting and brief air-drying. Finally, every fish was assigned to a life stage category (young, juvenile, or adult) based on the size criteria given by Mulligan (1981). After the fishes from each individual tow were processed, the results from all 7 tows were merged to form the data set for the station.

Due to the great quantity of fish data collected, only much-reduced summaries are presented herein. The minimally reduced data are available in the original thesis (Mulligan, 1981), archived at University Microfilms International (13-17, 894). Representative voucher series of all fish species are deposited in the museum collections of the University of Central Florida and the Florida State Museum at the University of Florida, Gainesville.

Measurement of Environmental Factors—Environmental parameters were measured, or water samples were taken, concurrently with fish sampling. Surface water temperature was measured in the field to the nearest 0.5°C. Surface salinity was measured in the field with an optical refractometer to the nearest part per thousand (ppt). The pH of a surface water sample was measured in the laboratory to the nearest 0.1 unit. Dissolved oxygen concentration was determined in the field from a water sample taken 1 m above the bottom. The Modified Winkler Titration method (Strickland and Parsons, 1972) was used to measure to 0.1 parts per million (ppm). Turbidity was measured in the laboratory from a surface water sample with a formazin-standardized turbidometer to the nearest 0.01 Nephelometric Turbidity Units (NTU). Depth was measured after each trawl tow to the nearest 0.1 m.

The substrate vegetative cover (seagrasses and drift algae) could not be observed directly at most stations. Thus, the relative amount of vegetation recovered in each 2-min trawl tow was used as an index of abundance. The contents of each tow were routinely dumped into a standard #2 galvanized wash tub and visual estimates were made of the tub fullness. Index values ranged from 0 to 10 in increments of 1 such that 0 = no vegetation recovered in the tub, 1 = tub one-tenth full of vegetation, 5 = tub one-half full, 10 = tub full to rim, etc. Tows that produced more than a tub full of vegetation (less than 5% of the tows over the entire study) were voided and repeated.

COMMUNITY INDICES AND STATISTICAL TESTS — A variety of standard descriptive indices were calculated from the data: number of species (S), mean number of species per tow, mean number of individuals per tow, Margalef's richness (D), Simpson's dominance index (SI), Shannon-Wiener diversity (H′), redundancy (R), evenness (J′), and secondary dominance (D_2). All the indices whose calculations are not self-explanatory are conveniently summarized by Livingston (1976) and Wilhm and Dorris (1968).

Within each month-station sample, an importance value (IV) index was calculated for each fish species. The IV index, slightly modified from its application in plant ecology (Mueller-Dombois and Ellenberg, 1974), combines frequency of capture, abundance, and size (biomass/individual) data. Each parameter was converted to a relative percentage for that month-station sample and the 3 relative values were added to yield an IV that ranged from 0 to 300.

IV = rf (relative frequency of capture) + ra (relative abundance) + rb (relative biomass per individual)
where:

$$\text{rf} = \frac{\text{frequency of capture of species A}}{\text{total frequency of capture of all species}} \text{ X } 100$$

$$\text{ra} = \frac{\text{individuals of species A caught}}{\text{total individuals of all species caught}} \text{ X } 100$$

$$\text{rb} = \frac{\text{biomass per individual for species A}}{\text{total biomass per individual for all species caught}} \text{ X } 100$$

After the IV value was calculated, species were ranked from highest IV (most important) to lowest IV (least important). IV rankings were also calculated for the 2 yr of study, both separately and combined, by the appropriate pooling of data sets.

Comparisons of environmental factors, abundance, dominance, and diversity among the 3 lagoon subareas were made using ANOVA followed by Duncan's Multiple Range Test. This procedure was also employed to examine the relationships of the 10 most abundant fish species to sequential trawl tows. Influences of environmental parameters on abundance of individual species were first identified by significant correlation coefficients. This procedure revealed that only salinity and vegetative cover were of possible importance in influencing abundance of certain fishes. Significant correlations were further evaluated by examination of scatter plots. In those cases where the relationship appeared to be meaningful, changes in abundance of the appropriate species with changing values of salinity or cover were examined using ANOVA followed by Duncan's Multiple Range Test. For these procedures, the environmental factors were recoded into 5 classes as follows: salinity 22-24 ppt = class 1, 25-27 = 2, 28-30 = 3, 31-33 = 4, 34-36 = 5; vegetative cover index 0-1 = class 1, 2-3 = 2, 4-5 = 3, 6-7 = 4, 8-10 = 5. In all statistical tests significance was $p < 0.05$.

SAMPLING BIAS — Although trawling is the preferred method for quantitative sampling of estuarine fish populations (Recksiek and McCleave, 1973; Livingston, 1976), gear bias does exist. Because a trawl is towed at relatively slow speed, collections are biased toward slower-swimming species. Juveniles of most species are taken in largest numbers because swimming speed is a function of fish length. Very small species may be lost through the large mesh of the wings and the trawl may "ride over" fishes that burrow in or lie on the bottom. Large amounts of macroalgae accumulating in the cod end may collapse the mouth of the trawl, causing it to fish improperly. On the other hand, small to moderate amounts of algae may act as a fine filter and help retain smaller fishes that otherwise might have been lost through the mesh.

Some of these biases are partially negated by repetitive trawling. The inherent advantages of this technique were first suggested by Taylor (1953) and were thoroughly explored by Livingston (1976). Furthermore, in areas such as the Indian River lagoon system, where accumulations of macroalgae are extensive, trawling by short repetitive tows is the only way trawling can be accomplished. In most cases, tows lasting 5-10 min accumulated such a load of algae that the net could not be hoisted from the water.

We investigated one aspect of the repetitive-trawling technique that has not been considered previously. If a species were frightened away from an area by trawling activities, it should be collected more frequently and in greater abundance in the first several (early) tows at a station, and might be absent or rare in progressively later tows. On the other hand, some fishes might be attracted to the disturbance caused by trawling and these species would be more frequent and abundant in later tows. An analysis for each of the 10 most numerous species revealed no significant differences in abundance between early, middle, and late tows at a station. This result further strengthens the justification for this technique and supports the validity of mean values calculated from the 7 sequential tows.

RESULTS

ENVIRONMENTAL FACTORS—Surface water temperatures were relatively uniform during the summer and varied only slightly from station to station. The lowest temperature, 28.0°C, was in Mosquito Lagoon and Banana River in July 1980. The highest temperature, 32.5°C, was in Indian River in August 1979. Overall means and ranges (in parentheses) for temperature (°C) in the 3 subareas were as follows: Mosquito Lagoon 29.6 (28.0-31.5), Indian River 29.9 (28.5-32.5), Banana River 29.6 (28.0-31.5). There also was little variation in pH. The only measurements below 7.0 were in Indian and Banana rivers in June 1980, and in Mosquito Lagoon in July 1980. Overall subarea means and ranges (in parentheses) for pH were as follows: Mosquito Lagoon 7.8 (6.7-8.3), Indian River 8.0 (6.7-8.6), Banana River 7.9 (6.6-8.5).

Turbidity was consistently low, never reaching a level of 5 NTU. The low turbidity levels reflect the lack of any major runoff or drainage into the northern part of the lagoon system. Variation in turbidity was caused by wind, water currents, local construction, and heavy boat traffic. The highest turbidity readings, in September 1979, were due to turbulence created by Hurricane David. Analysis revealed that Mosquito Lagoon was significantly ($p < 0.05$) more turbid than the other 2 subareas. Overall means and ranges (in parentheses) for turbidity (NTU) were as follows: Mosquito Lagoon 2.3 (0.7-4.7), Indian River 1.5 (0.3-3.3), Banana River 1.3 (0.3-2.2).

Daytime dissolved oxygen (DO) levels were always near saturation. Overall subarea means and ranges (in parentheses) for DO (ppm) were as follows: Mosquito Lagoon 5.4 (3.3-8.6), Indian River 6.4 (3.5-9.5), Banana River 5.1 (2.5-7.1). The relatively low DO concentrations in Mosquito Lagoon and Banana River are correlated with the times at which measurements were made. Mosquito Lagoon and Banana River stations were invariably sampled in the early morning hours, whereas Indian River stations were usually sampled in late morning or afternoon.

TABLE 1. Means and ranges of salinity (ppt) in subareas and sampling stations in the Indian River lagoon system, Florida, summers 1979 and 1980.

Subarea Station	# of Observations	Salinity $\bar{x}$ (range)
Mosquito Lagoon	16	33.8 (28-36)
1	8	33.7 (28-36)
2	8	33.9 (30-36)
Indian River	32	28.9 (22-35)
3	8	32.0 (28-35)
4	8	29.6 (22-32)
5	8	28.9 (24-32)
6	8	25.1 (22-27)
Banana River	16	25.4 (24-27)
7	8	25.9 (25-27)
8	8	24.9 (24-26)

Salinity varied considerably among the 3 basins in spite of only minor differences in tidal influence or fresh water inflow (Table 1). Mosquito Lagoon was significantly ($p < 0.05$) more saline than Indian River, which in turn was significantly more saline than Banana River. Snelson and Williams (1981) also noted this pattern of variation. The lowest salinity, 22 ppt, was at stations 4 and 6 in September 1979; the highest salinity, 36 ppt, was at stations 1 and 2 in September 1980. Mosquito Lagoon often becomes hypersaline in the dry season (winter and spring), with readings as high as 42 ppt (Snelson and Williams, 1981). Within the study area, salinities generally decreased from north to south. The cline was especially clear in Indian River. Station 3 in the north had salinity values near those of Mosquito Lagoon, whereas station 6 in the south had values almost identical to those of Banana River. Other salinity data for the Indian River lagoons were given by Grizzle (1974), Wilcox and Gilmore (1977), Gilmore (1977), and Snelson (1980).

A list of the most abundant species of macroalgae and/or seagrasses collected at each station is presented by Mulligan (1981). The index to the amount of vegetation collected monthly at each station and subarea is shown in Table 2. With a few exceptions (station 1, 1979 and station 6, 1980), the individual monthly, station, subarea, and overall means clearly show that more vegetation, primarily macroalgae, was present in Indian River than in the other 2 subareas. This difference was statistically significant ($p < 0.05$).

FISH POPULATIONS — A total of 57 fish species representing 29 families was collected during the study (Table 3). Eight species collected in 1979 were not taken in 1980, and 7 species collected in 1980 were not collected in 1979. Most species were taken in all 3 geographic subareas. However, 5 species

TABLE 2. Index to the amount of vegetation (primarily macroalgae) recovered in trawl tows in subareas and sampling stations in the Indian River lagoon system, Florida, summers 1979 and 1980. Each value in the body of the table is an average of the vegetation taken in the 7 replicate tows made at a station in any month, rounded to the nearest 1.0. See text for additional details.

Subarea Station	June 1979	July 1979	Aug. 1979	Sept. 1979	1979 $\bar{x}$	June 1980	July 1980	Aug. 1980	Sept. 1980	1980 $\bar{x}$	Overall $\bar{x}$
Mosquito Lagoon ($\bar{x}$)	1.5	2.5	2.0	2.5	2.1	2.0	5.0	1.0	5.0	1.0	1.5
1	3.0	5.0	4.0	5.0	4.2	4.0	1.0	2.0	1.0	2.0	3.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indian River ($\bar{x}$)	3.0	3.7	2.7	3.5	3.2	3.0	2.5	3.7	2.7	3.0	3.1
3	3.0	4.0	4.0	3.0	3.5	5.0	2.0	3.0	2.0	3.0	3.2
4	3.0	4.0	2.0	1.0	2.5	4.0	3.0	3.0	6.0	4.0	3.2
5	1.0	4.0	3.0	5.0	3.2	1.0	2.0	8.0	2.0	3.2	3.2
6	5.0	3.0	2.0	5.0	3.7	2.0	3.0	1.0	1.0	1.7	2.7
Banana River ($\bar{x}$)	4.0	3.5	1.5	1.0	2.5	2.0	1.0	2.5	1.5	1.7	2.1
7	2.0	4.0	1.0	1.0	2.0	3.0	1.0	2.0	2.0	2.0	2.0
8	6.0	3.0	2.0	1.0	3.0	1.0	1.0	3.0	1.0	1.5	2.2
Overall ($\bar{x}$)	2.9	3.4	2.2	2.6	2.8	2.5	1.6	2.7	1.9	2.2	2.5

TABLE 3. A list of fish species collected in the subareas of the Indian River lagoon system, Florida, summers 1979 and 1980. Nomenclature follows Robins et al., 1980; X = species collected; blank = species not collected. MI = Mosquito Lagoon, IR = Indian River, BR = *Banana River*.

	1979			1980		
Family, Scientific Name (Common Name)	ML	IR	BR	ML	IR	BR
Dasyatidae						
Dasyatis sabina (Atlantic stingray)		X	X	X	X	X
Dasyatis sayi (bluntnose stingray)	X		X	X		
Elopidae						
Elops saurus (ladyfish)						X
Clupeidae						
Brevoortia smithi (yellowfin menhaden)			X		X	X
Harengula jaguana (scaled sardine)	X	X	X	X	X	X
Opisthonema oglinum (Atlantic thread-herring)	X	X	X	X	X	X
Engraulidae						
Anchoa cubana (Cuban anchovy)	X	X	X		X	X
Anchoa hepsetus (striped anchovy)	X	X	X	X	X	X
Anchoa mitchilli (bay anchovy)	X	X	X	X	X	X
Ariidae						
Arius felis (hardhead catfish)	X	X	X	X	X	X
Bagre marinus (gafftopsail catfish)	X	X	X	X	X	X
Batrachoididae						
Opsanus tau (oyster toadfish)	X	X	X	X	X	X
Gobiesocidae						
Gobiesox strumosus (skilletfish)		X	X		X	
Cyprinodontidae						
Lucania parva (rainwater killifish)		X	X		X	X
Floridichthys carpio (goldspotted killifish)		X				
Poeciliidae						
Poecilia latipinna (sailfin molly)					X	
Syngnathidae						
Hippocampus erectus (lined seahorse)	X	X		X	X	X
Hippocampus zosterae (dwarf seahorse)	X	X	X		X	X
Syngnathus louisianae (chain pipefish)	X	X	X	X	X	
Syngnathus scovelli (gulf pipefish)	X	X	X	X	X	X
Serranidae						
Mycteroperca microlepis (gag)	X					
Echeneidae						
Echeneis naucrates (sharksucker)		X				
Carangidae						
Caranx hippos (crevalle jack)	X	X	X	X		
Chloroscombrus chrysurus (Atlantic bumper)		X		X		X
Oligoplites saurus (leatherjacket)		X	X			
Trachinotus carolinus (Florida pompano)				X	X	
Selene vomer (lookdown)	X					
Lutjanidae						
Lutjanus griseus (grey snapper)			X			
Gerreidae						
Diapterus auratus (Irish pompano)				X	X	X
Eucinostomus argenteus (spotfin mojarra)	X	X	X		X	X
Eucinostomus gula (silver jenny)	X		X	X		X
Haemulidae						
Orthopristis chrysoptera (pigfish)	X	X	X	X	X	X
Sparidae						
Archosargus probatocephalus (sheepshead)	X	X		X	X	
Lagodon rhomboides (pinfish)	X		X	X		X

TABLE 3 CONTINUED.

Family, Scientific Name (Common Name)	1979			1980		
	ML	IR	BR	ML	IR	BR
Sciaenidae						
Bairdiella chrysoura (silver perch)	X	X	X	X	X	X
Cynoscion nebulosus (spotted seatrout)	X	X	X	X	X	X
Cynoscion regalis (weakfish)	X	X	X	X	X	X
Leiostomus xanthurus (spot)	X	X	X	X	X	X
Menticirrhus americanus (southern kingfish)	X	X	X	X	X	X
Micropogonias undulatus (Atlantic croaker)	X	X	X	X	X	X
Pogonias cromis (black drum)				X		
Ephippidae						
Chaetodipterus faber (Atlantic spadefish)		X	X		X	X
Mugilidae						
Mugil curema (white mullet)				X		
Blenniidae						
Chasmodes saburrae (Florida blenny)	X	X	X		X	X
Gobiidae						
Gobionellus oceanicus (highfin goby)			X			X
Gobiosoma robustum (code goby)	X	X	X	X	X	X
Gobiosoma bosci (naked goby)		X				
Microgobius gulosus (clown goby)			X		X	X
Microgobius thalassinus (green goby)	X			X	X	
Triglidae						
Prionotus tribulus (bighead searobin)						X
Bothidae						
Citharichthys spilopterus (bay whiff)	X			X	X	
Paralichthys algibutta (gulf flounder)	X					
Soleidae						
Achirus lineatus (lined sole)	X	X		X	X	X
Cynoglossidae						
Symphurus plagiusa (blackcheek tonguefish)		X		X	X	
Balistidae						
Monacanthus hispidus (planehead filefish)	X	X		X	X	
Tetraodontidae						
Sphoeroides nephelus (southern puffer)	X	X	X	X	X	X
Diodontidae						
Chilomycterus schoepfi (striped burrfish)	X	X	X		X	X

were restricted to Indian River and Mosquito Lagoon samples; and 4 species were collected only in Banana River.

The community was numerically dominated by a very few species. The 15 most abundant fishes collected accounted for 99.54% of the total 2-yr catch (Table 4). One species, *Anchoa mitchilli*, comprised 87.47% of the 105,853 individuals taken during the 2 summers. Eighteen species were ranked in the top 15 by relative abundance for both sampling periods (Table 4).

The mean number of fishes collected per trawl tow was greatest in the Indian River (Table 5). This basin produced 22 and 62% more fish per tow than did Mosquito Lagoon and Banana River, respectively. The increased numbers in this subarea can be explained at least partially by the greater abundance of *Anchoa mitchilli* (Table 6).

TABLE 4. The relative abundance of the 15 most abundant epibenthic fish species collected in the Indian River lagoon system, Florida, summers 1979 and 1980. * = not ranked in top 15 by abundance.

	1979			1980			Overall		
Species	# Caught	% of Total	Rank	# Caught	% of Total	Rank	# Caught	% of Total	Rank
Harengula jaguana	102	0.21	12	53	0.09	*	155	0.15	15
Opisthonema oglinum	854	1.76	5	62	0.11	15	916	0.87	6
Anchoa hepsetus	285	0.59	6	380	0.65	6	665	0.63	7
Anchoa mitchilli	40,346	83.27	1	52,212	89.56	1	92,558	87.44	1
Arius felis	106	0.22	11	153	0.26	10	259	0.24	10
Bagre marinus	69	0.14	15	127	0.22	11	196	0.19	12
Lucania parva	182	0.38	8	41	0.07	*	223	0.21	11
Syngnathus scovelli	1,199	2.47	4	771	1.32	5	1,970	1.86	4
Diapterus auratus	0	0.00	*	156	0.27	9	156	0.15	14
Eucinostomus argenteus	102	0.21	13	5	0.01	*	107	0.10	*
Orthopristis chrysoptera	47	0.09	*	97	0.17	12	144	0.13	*
Lagodon rhomboides	274	0.56	7	257	0.44	8	531	0.50	8
Bairdiella chrysoura	1,490	3.08	3	1,227	2.10	2	2,717	2.60	2
Cynoscion regalis	39	0.08	*	87	0.15	13	126	0.11	*
Leiostomus xanthurus	137	0.28	10	1,223	2.10	3	1,360	1.30	5
Menticirrhus americanus	96	0.20	14	76	0.13	14	172	0.16	13
Micropogonias undulatus	149	0.31	9	319	0.55	7	468	0.44	9
Gobiosoma robustum	1,805	3.72	2	838	1.44	4	2,643	2.50	3
Overall Totals	47,282	99.43		58,084	99.63		105,366	99.54	
Total fish caught	47,553			58,300			105,853		

TABLE 5. The mean number of fishes caught per trawl tow in subareas and sampling stations in the Indian River lagoon system, Florida, summers 1979 and 1980.

Subarea Station	June 1979	July 1979	Aug. 1979	Sept. 1979	1979 $\bar{x}$	June 1980	July 1980	Aug. 1980	Sept. 1980	1980 $\bar{x}$	Overall $\bar{x}$
Mosquito Lagoon ($\bar{x}$)	260	359	351	343	328	38	118	316	78	137	232
1	471	701	227	68	367	72	154	542	60	207	287
2	49	18	475	619	290	5	83	91	96	69	179
Indian River ($\bar{x}$)	485	42	205	72	201	184	583	262	555	396	298
3	1,585	94	225	31	484	112	10	57	1,558	434	459
4	196	41	25	8	67	16	2,212	51	63	585	326
5	73	18	50	60	50	290	11	93	247	160	105
6	85	16	552	189	203	320	98	849	351	404	303
Banana River ($\bar{x}$)	76	39	324	25	116	47	42	192	163	111	113
7	119	28	615	20	195	38	21	18	67	36	115
8	32	50	34	30	36	56	63	336	260	186	111
Overall ($\bar{x}$)	326	121	272	128	211	114	331	258	338	260	235

TABLE 6. The 15 most abundant fish species collected in the subareas of the Indian River lagoon system, Florida, summers 1979 and 1980. For Indian River, the number of individuals caught is adjusted by dividing by 2 because there was twice as much sampling effort in Indian River as in the other two subareas (4 stations as opposed to 2).

	Mosquito Lagoon			Indian River			Banana River		
Species	#	Rank	%	Adj. #	Rank	%	#	Rank	%
Harengula jaguana	8	13	0.03	52	10	0.16	42	13	0.34
Opisthonema oglinum	51	10	0.20	83	6	0.25	699	2	5.62
Anchoa hepsetus	43	11	0.17	201	5	0.60	220	5	1.80
Anchoa mitchilli	21,886	1	84.70	30,377	1	91.20	9,918	1	79.67
Arius felis	56	9	0.22	70	8	0.21	62	10	0.50
Bagre marinus	79	8	0.31	49	11	0.15	19	15	0.15
Lucania parva	0	15	0.00	79	7	0.24	64	9	0.51
Syngnathus scovelli	315	6	1.20	682	3	2.05	201	6	1.61
Diapterus auratus	8	13	0.03	3	14	0.01	142	8	1.14
Lagodon rhomboides	227	7	0.88	0	15	0.00	304	4	2.44
Bairdiella chrysoura	945	3	3.70	651	4	1.90	470	3	3.80
Leiostomus xanthurus	1,219	2	4.70	45	12	0.14	50	11	0.40
Menticirrhus americanus	25	12	0.10	63	9	0.19	20	14	0.16
Micropogonias undulatus	361	5	1.40	29	13	0.09	48	12	0.38
Gobiosoma robustum	612	4	2.40	921	2	2.80	189	7	1.51
Overall Totals	25,835			33,308			12,448		

Although most species were collected at all stations, there were inequities in the numbers of individuals collected in the 3 subareas (Table 6). For example, over 30,000 (adjusted number) *Anchoa mitchilli* were collected in Indian River and over 20,000 were taken in Mosquito Lagoon, but less than 10,000 were caught in Banana River. The Indian River produced over twice as many *Syngnathus scovelli* as did Mosquito Lagoon and over 3 times the number collected in Banana River. Over 1200 *Leiostomus xanthurus* were collected in Mosquito Lagoon whereas only about 50 were collected in the other 2 basins. However, some relatively striking differences in catch between subareas were not statistically significant because of extensive variability within subareas. The following cases were significant ($p < 0.05$). Mosquito Lagoon produced more *Micropogonias undulatus* and *Leiostomus xanthurus* than did either Indian or Banana river. Indian River produced more *Syngnathus scovelli* than either Mosquito Lagoon or Banana River. In addition, more *Anchoa mitchilli* and *Menticirrhus americanus* were collected in Indian River than in Banana River. Finally, the Banana River yielded more *Lagodon rhomboides* than did Indian River.

Station 2 in southern Mosquito Lagoon was unique in several respects. No measurable amount of macroalgae or seagrass was present at this site (Table 2). In addition, large numbers of ctenophores were consistently trawled along with the fish samples; ctenophores were uncommon at other stations. This station produced large numbers of sciaenid fishes, in particular *Leiostomus xanthurus* and *Micropogonias undulatus*. Of the 1,219 *Leiostomus xanthurus* collected in Mosquito Lagoon, 947 were collected at station 2. Over the entire study this station alone accounted for 70% of the total individuals of this species collected. Additionally, station 2 produced 88% of the *Micropogonias undulatus* collected in this subarea and 67% of the 2-yr total for the study region. In contrast, *Syngnathus scovelli* and *Gobiosoma robustum*, species usually associated with algae and/or seagrasses, were poorly represented at station 2. Only 4 of the 315 *Syngnathus scovelli* collected in Mosquito Lagoon were taken at station 2. Over the entire study this station accounted for only 0.2% of the total individuals of this species collected. Furthermore, station 2 produced only 8% of the *Gobiosoma robustum* collected in the basin and less than 2% of the 2-yr total. Although station 2 was clearly the most divergent of the 8 stations studied, each station had its own subtle peculiarities in fish relative abundance.

DOMINANCE AND DIVERSITY—In an analysis of the Apalachicola Bay fish community, Livingston (1976) showed a high degree of correlation among several species diversity indices. Our results are in agreement. Simpson's index, Shannon-Wiener's index, redundancy, evenness, richness, and relative dominance are significantly correlated (Table 7). Furthermore, all 6 measures are significantly correlated with the percent *Anchoa mitchilli* (# *A. mitchilli* ÷ total # fishes collected at a station). Changes in the abundance and relative dominance of this single species largely dictate the values of

TABLE 7. Pearson correlation matrix for 10 fish community indices calculated from 64 month/station samples from the Indian River lagoon system, Florida, summers 1979 and 1980. S = no. of species, $\overline{X}_1$ = mean no. individuals per tow, $\overline{X}_2$ = mean biomass per tow, D = Margalef's richness index, SI = Simpson's diversity index, H′ = Shannon-Wiener diversity index, R = redundancy, J′ = evenness, D_2 = relative (secondary) dominance, % A.M. = no. *Anchoa mitchilli* ÷ total no. individuals collected.
* = $p<0.05$.

Index	S	$\overline{X}_1$	$\overline{X}_2$	D	SI	H′	R	J′	D_2	% A.M.
S	1.00	0.08	0.42*	0.77*	−0.05	0.13	0.04	−0.09	−0.11	0.11
$\overline{X}_1$		1.00	0.71*	−0.36*	0.63*	−0.62*	0.62*	−0.65*	0.52*	0.51*
$\overline{X}_2$			1.00	−0.03	0.40*	−0.38*	0.42*	−0.47*	0.33*	0.34*
D				1.00	−0.57*	0.66*	−0.49*	0.48*	−0.61*	−0.34*
SI					1.00	−0.98*	0.98*	−0.98*	0.92*	0.87*
H′						1.00	−0.97*	0.97*	−0.96*	−0.83*
R							1.00	−0.99*	0.94*	0.87*
J′								1.00	−0.92*	−0.88*
D_2									1.00	0.78*
% A.M.										1.00

most of the diversity indices utilized. Because of the high correlation among the indices, we will consider only 3 in detail, number of species (S), relative dominance (D_2; Livingston, 1976), and the Shannon-Wiener index (H′).

Significantly more species ($p < 0.05$) were collected at stations in Mosquito Lagoon and Banana River than at stations in Indian River (Table 8). Despite this inequity, there was only slight variation in monthly subarea totals; and the mean number of species caught per station over the entire study was 13. Values ranged from a low of 6 (station 3, August 1979 and station 2, June 1980) to a high of 23 (station 7, August 1979).

There was little variation in overall subarea and station means for relative dominance (Table 9). The slightly lower values and broader range in Banana River correlate with the higher species diversity levels found in the subarea. The consistently high values of this dominance measure reflect the numerical predominance of a few species. *Anchoa mitchilli* dominated numerically at virtually all study stations in all months. Over the entire study, it was the first dominant species in 51 of 64 month-station samples, and was the second dominant species in two samples. The second dominant species was more variable. In Mosquito Lagoon, *Bairdiella chrysoura* was the second dominant in 7 of the 16 month-station samples. *Leiostomus xanthurus* and *Anchoa mitchilli* were each second dominant twice. *Gobiosoma robustum* and *Syngnathus scovelli* were the most frequent second dominant species in Indian River, 11 and 9 times, respectively, out of the 32 month-station samples. No single species led in secondary dominance in Banana River. *Bairdiella chrysoura* was the second dominant 5 times and *Anchoa hepsetus* 3 times out of 16 month-station samples.

The Banana River had the greatest overall Shannon-Wiener diversity index, 1.85 (Table 10). The highest monthly value (3.59) and 4 of the 5 highest monthly values were found in this subarea. The high values in Banana River reflect the greater number of species and less prominent dominance found there. In contrast, the 6 lowest monthly values were all found in Indian River, reflecting the lower number of species and the predominance of *Anchoa mitchilli*. Although Mosquito Lagoon had an overall diversity index identical to that of Indian River, there was much less variability in Mosquito Lagoon.

IMPORTANCE VALUES—Seventeen species were ranked in the top 15 by importance value (IV) over both sampling periods (Table 11). *Anchoa mitchilli* ranked first in both years with an IV of 4 (1979) and 6 (1980) times greater than the second ranked species. The greatest changes in rank between the 2 yr (1979 vs. 1980) occurred in *Opisthonema oglinum* (rank 8 to rank 14), *Bagre marinus* (13 to 8), *Micropogonias undulatus* (12 to 5), and *Gobiosoma robustum* (4 to 9). The overall IV's for ranks 2, 3, and 4 were sufficiently spaced so that additional sampling probably would not have affected their positions. However, the IV's for inclusive ranks 5 through 8, 9 through 11, and 13 through 15 were sufficiently close together that further

TABLE 8. The total number of fish species collected in subareas and sampling stations in the Indian River lagoon system, Florida, summers 1979 and 1980.

Subarea Station	June 1979	July 1979	Aug. 1979	Sept. 1979	1979 $\bar{x}$	June 1980	July 1980	Aug. 1980	Sept. 1980	1980 $\bar{x}$	Overall $\bar{x}$
Mosquito Lagoon	23	23	24	24	23	16	22	22	23	21	22
1	19	16	15	16	16	13	18	20	14	16	16
2	13	15	13	17	14	6	16	12	17	13	13
Indian River	29	22	19	27	24	25	19	25	29	24	24
3	14	16	6	17	13	12	9	13	15	12	12
4	19	8	12	7	11	7	9	12	18	11	11
5	16	9	11	13	12	15	12	11	7	11	11
6	18	10	12	21	15	14	7	18	15	13	14
Banana River	19	23	28	17	22	21	20	23	22	21	21
7	10	13	23	13	15	15	14	20	18	17	16
8	17	20	16	12	16	15	14	16	13	14	15
Overall ($\bar{x}$)	16	13	13	14	14	12	12	15	15	13	13

TABLE 9. Relative dominance (D_2) in the epibenthic fish community in subareas and sampling stations of the Indian River lagoon system, Florida, summers 1979 and 1980.

Subarea Station	June 1979	July 1979	Aug. 1979	Sept. 1979	1979 $\bar{x}$	June 1980	July 1980	Aug. 1980	Sept. 1980	1980 $\bar{x}$	Overall $\bar{x}$
Mosquito Lagoon ($\bar{x}$)	0.91	0.75	0.94	0.88	0.87	0.82	0.71	0.84	0.80	0.79	0.83
1	0.94	0.98	0.92	0.79	0.91	0.82	0.77	0.96	0.93	0.87	0.89
2	0.89	0.52	0.97	0.97	0.84	0.82	0.66	0.72	0.68	0.72	0.78
Indian River ($\bar{x}$)	0.85	0.72	0.87	0.72	0.79	0.85	0.84	0.87	0.90	0.86	0.82
3	0.99	0.66	0.96	0.66	0.82	0.66	0.81	0.76	0.99	0.80	0.81
4	0.89	0.94	0.71	0.71	0.81	0.78	0.99	0.80	0.69	0.81	0.81
5	0.86	0.60	0.82	0.67	0.74	0.98	0.63	0.93	0.99	0.88	0.81
6	0.67	0.69	0.99	0.83	0.79	0.98	0.94	0.98	0.95	0.96	0.87
Banana River ($\bar{x}$)	0.75	0.60	0.76	0.77	0.72	0.80	0.80	0.66	0.92	0.79	0.75
7	0.92	0.52	0.94	0.77	0.79	0.75	0.67	0.37	0.90	0.67	0.73
8	0.59	0.69	0.59	0.78	0.66	0.86	0.94	0.95	0.95	0.92	0.79
Overall ($\bar{x}$)	0.84	0.70	0.86	0.77	0.79	0.83	0.80	0.81	0.88	0.83	0.81

TABLE 10. Shannon-Wiener species diversity in the epibenthic fish community in subareas and sampling stations of the Indian River lagoon system, Florida, summers 1979 and 1980.

Subarea Station	June 1979	July 1979	Aug. 1979	Sept. 1979	1979 $\bar{x}$	June 1980	July 1980	Aug. 1980	Sept. 1980	1980 $\bar{x}$	Overall $\bar{x}$
Mosquito Lagoon ($\bar{x}$)	1.10	1.64	0.61	1.18	1.13	1.68	2.05	1.34	1.51	1.64	1.38
1	1.00	0.34	0.80	1.84	0.99	1.65	1.93	0.56	0.78	1.23	1.11
2	1.20	2.94	0.42	0.53	1.27	1.71	2.17	2.12	2.25	2.06	1.66
Indian River ($\bar{x}$)	1.29	1.99	1.09	2.06	1.61	1.13	1.40	1.23	0.83	1.15	1.38
3	0.17	2.19	0.51	2.29	1.29	2.08	1.95	1.84	0.06	1.48	1.38
4	1.10	1.38	2.15	2.13	1.69	1.87	0.13	1.89	2.35	1.56	1.62
5	1.55	2.31	1.45	2.03	1.83	0.39	2.55	0.74	0.07	0.94	1.38
6	2.35	2.10	0.24	1.80	1.62	0.20	0.96	0.47	0.84	0.62	1.12
Banana River ($\bar{x}$)	1.77	2.60	1.93	1.84	2.03	1.74	1.83	2.10	1.02	1.67	1.85
7	0.81	2.72	1.04	2.00	1.64	1.94	2.36	3.59	1.44	2.33	1.98
8	2.74	2.48	2.82	1.68	2.43	1.55	1.31	0.60	0.60	1.01	1.72
Overall ($\bar{x}$)	1.36	2.06	1.18	1.79	1.60	1.42	1.67	1.48	1.05	1.40	1.50

TABLE 11. Importance values (IV) and IV rankings of the top 15 epibenthic fish species collected in the Indian River lagoon system, Florida, summers 1979 and 1980. * = not ranked in top 15.

Species	1979 Rank	1979 (IV)	1980 Rank	1980 (IV)	Overall Rank	Overall (IV)
Harengula jaguana	11	(6.8)	*	---	14	(4.3)
Opisthonema oglinum	8	(9.3)	14	(4.5)	11	(7.5)
Anchoa hepsetus	10	(7.0)	6	(11.8)	5	(10.0)
Anchoa mitchilli	1	(122.0)	1	(129.8)	1	(125.6)
Arius felis	3	(18.3)	3	(20.2)	3	(20.9)
Bagre marinus	13	(6.0)	8	(7.8)	12	(6.6)
Lucania parva	15	(4.7)	*	---	*	---
Syngnathus scovelli	7	(10.4)	11	(6.9)	9	(7.8)
Orthopristis chrysoptera	*	---	13	(5.0)	*	---
Lagodon rhomboides	6	(10.4)	7	(8.4)	6	(9.3)
Bairdiella chrysoura	2	(30.8)	4	(19.1)	2	(24.5)
Cynoscion regalis	*	---	12	(6.6)	13	(5.0)
Leiostomus xanthurus	5	(11.1)	2	(22.4)	4	(16.7)
Menticirrhus americanus	9	(8.6)	10	(7.0)	10	(7.6)
Micropogonias undulatus	12	(6.2)	5	(12.2)	8	(9.1)
Gobiosoma robustum	4	(11.2)	9	(7.7)	7	(9.1)
Sphoeroides nephelus	14	(4.7)	15	(3.9)	15	(4.3)

data collection might have caused changes in ranks within the respective sets but would have produced little change in the basic composition of the ranked list.

DISCUSSION

The objective of this fish sampling program was to develop a cost-effective data base to serve as a quantitative baseline for future long-range monitoring. The study was based on sampling a relatively small number of stations during 4 mo of a single season for 2 consecutive years. Sampling in a single season avoided the statistical difficulties of dealing with annual cycles in distribution and abundance of fish species. Summertime sampling also proved ideal in regard to climatic conditions and logistics. In addition, we believe that this sampling scheme produced an adequate data base at minimal cost. Increased sampling, either spatially or temporally, would have led to increased expense but would not necessarily have provided a better baseline for long-range assessment of the fish community.

The 57 species collected comprise about one-half of the total species known to inhabit this portion of the lagoon system (Snelson, 1982), and most if not all are year-round inhabitants. Most of the individuals collected belong to relatively few species and the most abundant species was *Anchoa mitchilli*, situations typical in estuarine systems throughout the southeast (Dahlberg and Odum, 1970; Swingle, 1971; Livingston et al., 1976; Ogren and Brusher, 1977).

In a year-round study, Snelson (1980) found water temperature and turbidity to be weakly but significantly correlated with several fish community

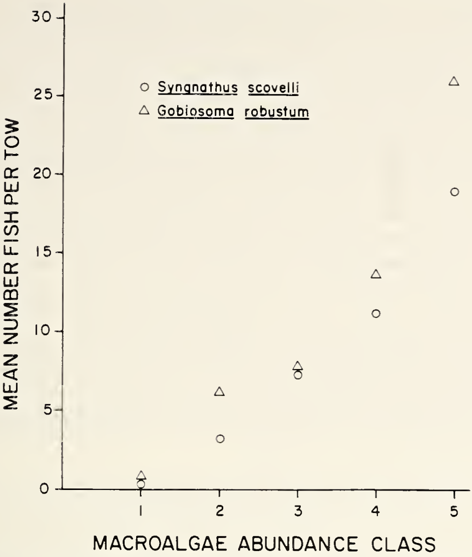

Fig. 2. Graph of the mean number of *Syngnathus scovelli* and *Gobiosoma robustum* per trawl tow within each macroalgae abundance class.

parameters in this same study region. We found no statistically significant correlation between depth, temperature, pH, turbidity, salinity, or dissolved oxygen and any index of diversity, richness, or abundance in the fish community. The abundance of selected species, however, was influenced by vegetative cover and salinity. Catches of *Gobiosoma robustum* and *Syngnathus scovelli* were positively correlated with vegetative cover (Fig. 2), and both Snelson (1980) and Kulczycki et al. (1981) noted the positive association of these 2 species with drift algae. The far greater catches of these species in Indian River (Table 6) can be attributed to the greater abundance of vegetation, primarily macroalgae, there (Table 2). *Bairdiella chrysoura* also showed a positive association with cover, but the trend was not linear. Mean catches of this species were not significantly different in the three lowest algae classes, but there was an abrupt and significant ($p < 0.05$) increase in abundance in tows with cover indices of 6 and greater. *Micropogonias undulatus* and *Leiostomus xanthurus* showed a trend for increasing abundance with increasing salinity, and the catches were significantly higher ($p < 0.05$) at salinities above 34 ppt. Both species were significantly more abundant in Mosquito Lagoon, the most saline basin, than in the other 2 basins. Elsewhere in Florida, Parrish and Yerger (1973) also found that *L. xanthurus* abundance was positively associated with salinity. *Lagodon rhomboides* was most abundant in the Banana River, the least saline subarea, contrasting with the positive correlation between its abundance and salinity reported by Subrahmanyam and Drake (1975).

We can only speculate as to why stations in the most and least saline basins, Mosquito Lagoon and Banana River respectively, produced the greatest number of species (Table 8); whereas Indian River produced the greatest mean number of fish per trawl tow, primarily *Anchoa mitchilli* (Table 5). Perhaps the high species diversity in Mosquito Lagoon and Banana River is due to their less disturbed environmental conditions. No causeways yet traverse Mosquito Lagoon and its shoreline remains essentially undeveloped, especially in those areas included within the Merritt Island National Wildlife Refuge. In addition, boat traffic is minimal in the undredged southern section, which included station 2. The northern part of Banana River is located within the security perimeter of the J. F. Kennedy Space Center and the Cape Canaveral Air Force Station. The area is closed to commercial and sport fishing and most boat traffic. There is no private development on the shores. Other than in the immediate vicinity of the Port Canaveral Locks, there are few parts of the northern Banana River continually impacted by man's activities.

Of the 3 subareas, Indian River is clearly the most heavily impacted by man's activities. It also has the lowest average species diversity. The Indian River is subdivided by 4 causeways in the study area. It carries considerable boat traffic, including large barges, fishing vessels, and private yachts that ply the Intracoastal Waterway. There are 2 fossil-fuel burning power plants on the western shore that emit heated effluents. The Indian River receives waste water from Kennedy Space Center and Titusville and numerous small industries along the western shore. The western shore is developed virtually the full length of the study region.

The heterogeneous data collected in this study are a result of 2 factors, (1) the inherent variability found in estuarine biological systems and (2) the variability associated with sampling fish populations, which often show contagious distributions (Bechtel and Copeland, 1970; McErlean et al., 1973). Because of this variability, it is usually difficult to demonstrate and statistically defend temporal and/or spatial changes in distribution and absolute abundance of fish species. As a consequence, most authors (e.g., Dahlberg and Odum, 1970; Turner and Johnson, 1973; Livingston, 1976; Ogren and Brusher, 1977) simply rank species on the basis of relative abundance. However, ranking by relative Importance Value (IV) has advantages over ranking by abundance; and, in our opinion, IV is the best index for the evaluation of change in long-range monitoring of the lagoon fish community. Ranking by relative abundance to determine dominance is certainly fast and simple, because the only datum needed is number of individuals of each species captured. However, because size of the individuals and their frequency of capture are not considered, relative abundance alone is neither intellectually satisfying nor ecologically sound. Intuitively, a 0.1 g *Lucania* *parva* and a 1.0 kg *Arius felis* cannot be equal in a functional sense. The larger fish certainly demands more of its habitat in terms of nutrients and space; consequently, it must have a greater impact on the environment. Furthermore, some species may be abundant in one limited area but uncommon elsewhere; whereas other species may be less abundant but widely distributed. Relative abundance alone makes abundant but localized species appear disproportionately significant. Because the IV index also evaluates frequency of capture, this problem is at least partially negated. Finally, IV is responsive to changes in size (biomass) distribution that may occur with or without accompanying changes in abundance. For example, if a species failed to spawn successfully during its reproductive season, the absence of young-of-the-year in succeeding samples would influence the size of an average individual, thereby altering IV.

The top 15 species ranked on relative abundance and IV over the entire study are compared in Table 12. The first, second, and twelfth ranked species are the same on both lists and the 2 lists contain ten other species in common. Although there is not a great difference between the 2 lists in the rankings of these 10 species, the ranking by IV is most realistic. *Lucania parva*, for example, was one of the 15 most abundant fishes collected; but due to its small size and infrequent capture, it was not ranked in the top 15 by IV. On the other hand, *Cynoscion regalis* and *Sphoeroides nephelus* were also collected infrequently but the individuals collected were usually quite large compared to other species taken. Consequently, neither was ranked in the top 15 species by relative abundance; but both were high in the IV ranking. Finally, *Diapterus auratus* was ranked fourteenth on the basis of abun-

TABLE 12. Overall relative abundance and importance value rankings of the top 15 epibenthic fish species collected in the Indian River lagoon system, Florida, summers 1979 and 1980.

Relative Abundance		Importance Value	
Rank	Species	Rank	Species
1.	*Anchoa mitchilli*	1.	*Anchoa mitchilli*
2.	*Bairdiella chrysoura*	2.	*Bairdiella chrysoura*
3.	*Gobiosoma robustum*	3.	*Arius felis*
4.	*Syngnathus scovelli*	4.	*Leiostomus xanthurus*
5.	*Leiostomus xanthurus*	5.	*Anchoa hepsetus*
6.	*Opisthonema oglinum*	6.	*Lagodon rhomboides*
7.	*Anchoa hepsetus*	7.	*Gobiosoma robustum*
8.	*Lagodon rhomboides*	8.	*Micropogonias undulatus*
9.	*Micropogonias undulatus*	9.	*Syngnathus scovelli*
10.	*Arius felis*	10.	*Menticirrhus americanus*
11.	*Lucania parva*	11.	*Opisthonema oglinum*
12.	*Bagre marinus*	12.	*Bagre marinus*
13.	*Menticirrhus americanus*	13.	*Cynoscion regalis*
14.	*Diapterus auratus*	14.	*Harengula jaguana*
15.	*Harengula jaguana*	15.	*Sphoeroides nephelus*

dance. However, 142 of the 156 collected (91%) were taken in the Banana River. This species obviously was not dominant in terms of frequency of capture or widespread distribution in the study area.

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Academy Symposium

FACTORS INFLUENCING SEAGRASS ECOLOGY IN THE INDIAN RIVER LAGOON

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ABSTRACT: *Effects of water depth, water temperature, light intensity, epiphyte coverage, detrital accumulation and sediment resuspension and shifting on seagrass ecology in the Indian River Lagoon system were studied from April 1977 through June 1979. Seagrass beds containing* Halophila engelmannii, Halodule wrightii *and* Syringodium filiforme *located between Cocoa and Grant, Florida, were chosen as sampling sites. Increases in vegetative growth for all 3 seagrasses occurred in spring and to a lesser extent in fall months. Water temperatures ranged between 22 and 30°C. Decreased detrital accumulation, sediment resuspension and shifting, and water depth, increased light transmission and intensities at the seagrass blade level, and reduced epiphytic coverage (less than 300 mg epiphytes/gm blade) were observed during spring. Overall epiphyte levels (expressed as seasonal averages) were 850, 615 and 210 mg epiphytes/gm blade for* Syringodium, Halodule *and* Halophila, *respectively. Net photosynthetic rates were highest during spring and fall, 1185, 1090 and 670 μg C fixed/mg Chl-hr. Periods of decreased vegetative growth (in summer and winter months) were accompanied by increased blade necrosis, rhizome and/or blade detachment, more dense epiphyte coverage (in excess of 100 mg epiphytes/gm blade) and reduced photosynthetic rates. Decreased light intensities at blade level, sub-optimal temperatures (< 20°C in winter and > 30°C in summer), and extensive sediment shifting and detrital accumulation were observed at these times.*

SEASONAL variations in productivity of seagrasses have been reported for

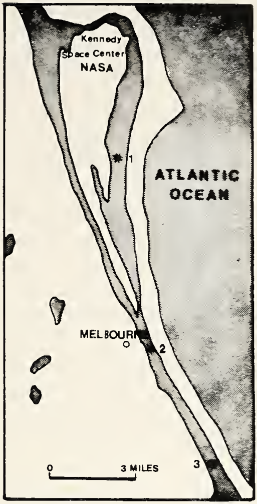

FIG. 1. Study Area: (1) Cocoa, Florida collection site, (2) Melbourne, Florida collection site, (3) Grant, Florida collection site.

the Mediterranean (Drew, 1978, 1979), the Bering Sea (McRoy, 1974), the Pacific coast of Japan (Mukai et al., 1979), shallow estuarine systems of the coast of North Carolina (Penhale, 1977) and extensively reviewed by McRoy and McMillan (1977). Similar studies of seagrass standing stocks are reported for the Indian River lagoonal system (Phillips, 1960; Thomas, 1974; Gilbert, 1976; Gilbert and Clark, 1981). However, an understanding of interrelationships between abiotic and biotic factors influencing distribution and seasonal variations in vegetative capacity is still very limited.

We evaluate the influence of biotic and abiotic parameters on the seasonal changes in seagrass beds containing *Halodule wrightii*, *Halophila engelmannii* and *Syringodium filiforme*. In addition, the capacity for vegetative growth was measured by [^{14}C] uptake and compared to observed seasonal vegetative patterns.

DESCRIPTION OF STUDY AREA — The study was conducted on several seagrass beds containing *Halophila engelmannii*, *Halodule wrightii* and *Syringodium filiforme* in the Indian River between Cocoa and Grant, Florida (Fig. 1). The area, a large shallow mesohaline lagoon, is isolated from the Atlantic Ocean by a barrier island forming its entire eastern shore. As a result, direct exchange between the 2 bodies of water and tidal flux in the study area are negligible. The weak north to south currents in the lagoon are largely wind induced (Schneider, et al., 1974) and are attenuated by the numerous causeways and islands located throughout the system. Much of the water input is from runoff or direct precipitation. Sediments are highly detrital, fine grain sands. Seasonal accumulation, shifting and wind-induced resuspension of these sediments in and around the seagrass beds occur continually and are important factors affecting distribution and abundance of seagrass species.

The seagrasses examined in this area are found throughout the lagoonal system as patches surrounded by open sandy areas in depths usually less than 1 m. This varies as a function of turbidity and sediment destabilization due to extensive boat traffic in the system at greater depths. *Halodule* and *Syringodium* are the more abundant seagrasses (Thompson, 1978), while beds containing *Halophila* are generally found as isolated patches in the deeper range of the seagrass habitat, or as a subdominant member in association with *Syringodium* stands. In shoreline stands containing all 3 seagrasses, an apparent depth zonation is observed in which the *Halodule* dominates in the shallowest areas, followed by *Syringodium* and then *Halophila*.

MATERIALS AND METHODS—Seagrass beds containing *Halodule*, *Syringodium* and *Halophila* were examined from April 1977 through June 1979. The study consisted of 2 phases: (a) examination of biotic and abiotic influences on seagrass ecology; (b) determination of seagrass vegetative capacities by *in vitro* [^{14}C] incorporation.

Biotic and Abiotic Parameter Study: Immediately prior to blade sampling, water and air temperature, water depth and salinity (by refractive index) were measured. Samples of the seagrasses and their attached epiphytes were harvested and transported to the laboratory in plastic bags containing water from the sampling site to prevent desiccation. In the laboratory, epiphytes were separated from the blades by careful scraping with razor blades. This method was found to be more effective than either sonication or scraping samples after freezing. After scraping, the seagrasses and epiphytes were placed in a drying oven for 48 to 96 hr and dry weights determined. Epiphyte coverage is expressed as mg epiphytes per gram seagrass blade (dry weight).

Photosynthetically active radiation (PAR, 380 to 700 nm) intensities (μE/m^2-sec) were measured at the air-water interface (S.I.) and at mean seagrass blade depth (B.I.) using a LICOR quantum radiometer (model LI-185A). Measurements were generally obtained between 1000 and 1400 E.S.T. In addition to obtaining direct PAR flux at the sites, these measurements were also used to determine an index of water clarity (in the form of per cent PAR transmission) by the formula:

$$\% \text{ PAR Transmission} = (\text{B.I./S.I.}) \times 100$$

In conjunction with measurement of physical parameters, observations on the environmental quality in and around the seagrass beds were made. Phases of seagrass vegetative growth and decline, the extent of epiphytic coverage on seagrass blades, sediment accumulations and shifting in and around the beds, water conditions and general weather patterns were recorded at the various sites throughout the study.

Incorporation Study: Photosynthetic rates, as determined by [^{14}C] incorporation into acid stable metabolites, were used as the means for determining seagrass vegetative capacity (Bassham and Calvin, 1957). Intact plants of each species were collected on the morning of each experiment. Leaf tissue samples (approximately 75 to 100 mg) were excised, cleaned of epiphytes and placed in filter sterilized seawater (FSSW). FSSW was prepared by filtration through #4 Whatman followed by millipore filtration (0.45 μ). Bicarbonate concentration was determined by the method of Strickland and Parsons (1972) and salinity calculated as previously described.

Tissue samples were equilibrated at 700 μE/m^2-sec for 10 min at 30°C, transferred to 5 ml FSSW containing 15 μl [^{14}C] bicarbonate (1 mCi/ml, 50 mCi/mM), and allowed to incorporate under 700 μE/m^2-sec PAR at 30°C for 15 min. Tissues were then rinsed thoroughly with deionized (DI) water, homogenized and extracted with 1 ml hot methanol (x4) and final pellets extracted with 1 ml DI water (x4). Chlorophyll was extracted from the methanol-water mixture using the ratio methanol-water:ether:water (1:1:1.2). Total chlorophyll in the ether phase was calculated according to Strain and Svec (1966). Radioactivity in the remaining methanol-water phase was determined by adding a 0.1 ml aliquot to 10 ml Aquasol-2 (New England Nuclear) and counted in a Beckman LS-100C scintillation counter (counting efficiency = 72%). Photosynthetic rate was determined as described by Goldman et al. (1974).

SITE MONITORING STUDY—Stands containing *Halodule* and *Syringodium* exhibited similar patterns of development and decline over the study period between April 1977 and May 1978. Vegetative periods, characterized by rhizome extension and rapid seagrass blade elongation, were observed during the spring of 1977 and continued into July. At that point, increased blade necrosis and detachment became evident, reaching a maximum in late August. Blade detachment was more extensive in *Syringodium* than *Halodule*. This period was followed by a second, less extensive, vegetative phase which lasted into late fall and consisted mainly of blade replacement rather than new rhizome formation. During the winter an overall decline in the beds was observed. Uprooting of complete plant systems, in addition to blade detachment, was common during this period. The beds remained thinned until late March 1978, when another vegetative phase was observed, which continued through the remainder of the monitoring study (May 1978). Reexamination of the beds from October 1978, through June 1979, showed the same general trends.

Observations at the *Halophila* stand initially chosen for monitoring (Fig. 1, Site 3) were suspended in October 1977 after noting a rapid decline and subsequent loss of above ground portions of this seagrass during midsummer. Although intact plants were located the following spring, concern over further disruption of the bed precluded resumption of sample collection of this species at this site. However, while this bed was monitored, patterns of physical parameter fluctuation and the spring vegetative phase were similar to those of other seagrasses. A similar decline was noted in another *Halophila* stand at Site 2. No return of this species was seen as of June 1979.

Biotic and abiotic parameters varied extensively. Water depth fluctuations (Fig. 2A) corresponded to the seasonal wet and dry periods observed in the area, and salinity (Fig. 2D) generally varied inversely with water depth. Although water and air temperatures (Fig. 2B) are shown only for Site 2, measurements at all sites were similar and reflected seasonal warming and cooling trends. Temperatures ranged from 13°C (water) and 11°C (air) at mid-day in winter to 32°C (water) and 36°C (air) in the summer. PAR intensities (Fig. 3) and percent PAR transmission (Fig. 2C) at the mean seagrass blade depth generally varied inversely with water depth (Fig. 2A). Periods of increased detrital accumulation and sediment shifts noted during summer and early winter of 1977 were accompanied by decreased PAR intensity and transmission measurements.

Epiphyte coverage (Fig. 4) also varied extensively. Increased seagrass blade necrosis and detachment were observed during periods of highest epiphytic coverage.

INCORPORATION STUDIES—*In vitro* [^{14}C] uptake experiments were per-

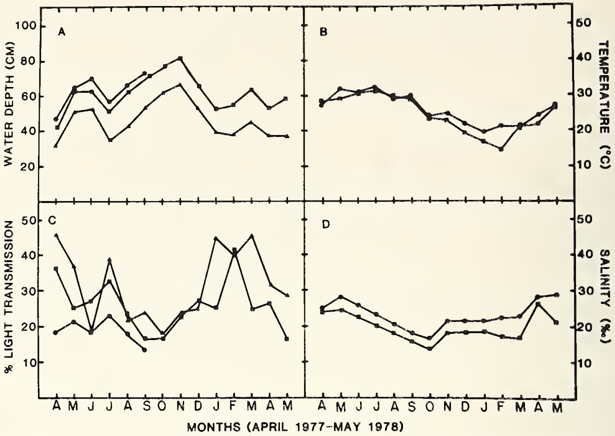

Fig. 2. Abiotic parameters in the system as monthly averages. (A) Water depth, *Halophila* bed (●——●) site #3; *Syringodium* bed (▲——▲) and *Halodule* bed (■——■) Site #2. (B) temperature at site #2 in water (■——■) and air (●——●). (C) Percent light transmission at mean blade depth for *Halophila* (●——●) site #3; *Syringodium* (▲——▲) and *Halodule* (■——■) site #2. (D) Salinity at the *Syringodium* bed (●——●) and *Halodule* bed (■——■) at site #2.

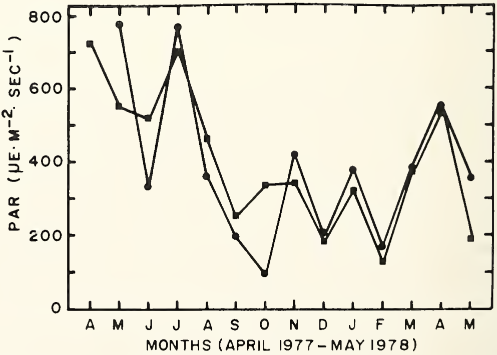

Fig. 3. Average PAR intensities at mean blade depth at site #2: *Syringodium* bed (●——●); *Halodule* bed (■——■).

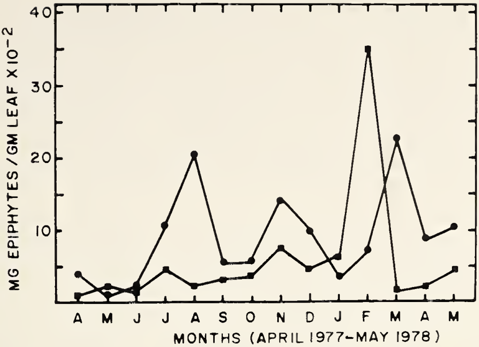

FIG. 4. Epiphytic coverage (dry weight basis) as monthly averages at site #2: *Syringodium* (●———●); *Halodule* (■———■).

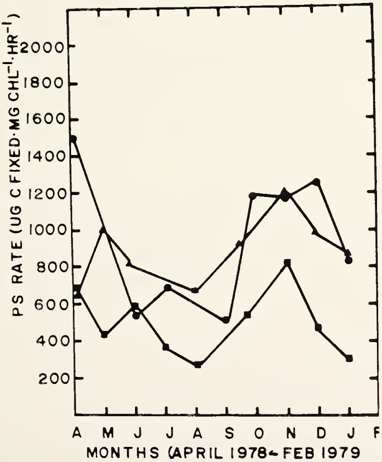

FIG. 5. Photosynthetic rates at 30°C and 700 μE/m²-sec as monthly averages: *Halophila* (●———●) site #1; *Halodule* (▲———▲) and *Syringodium* (●———●) site #2.

formed on the seagrasses from April 1978 through January 1979 to determine seasonal patterns in net photosynthetic capacity (Fig. 5). Overall average rates were 935, 905 and 485 μg C mixed mg Chl-hr for *Halophila*, *Halodule* and *Syringodium*, respectively. Periods associated with decreased photosynthetic rates were times of maximal chlorophyll concentrations in *Halophila* and *Halodule* (Fig. 6). Chlorophyll content in *Syringodium* was relatively unchanged, yet the seasonal pattern of photosynthetic rate was similar to that of the other seagrasses.

Incorporation studies were also performed to determine responses of the seagrasses to increasing PAR intensities (Fig. 7). Results show that near maximal photosynthetic rates are obtained at fairly low PAR intensities (approximately 200 to 300 $\mu E/m^2$-sec at 30°C).

Discussion—Increased vegetative growth in the seagrass beds was associated with moderate water temperatures (between 22° and 30°C), increased PAR intensities at the seagrass blade level, relatively low water depths, periods of decreased detrital accumulation and sediment shifting and low epiphyte coverage.

In vitro experiments to determine optimal temperatures for photosynthesis by seagrasses (Krepley, 1978) have shown that photosynthetic rates of *Halodule* and *Syringodium* increase with temperature and are near maximal at approximately 30°C, while rates for *Halophila* increased with temperature to about 36°C (Trocine, 1978). Rates decreased sharply at temperatures in excess of these maxima. Phillips (1960) has described "cold kill" in seagrasses found in Florida waters when temperatures fall below 20°C for an extended time. In this study, water temperatures between these extremes occurred during mid spring and early summer and again in mid fall, which coincides with increased vegetative growth observed in the seagrass beds. During mid summer when temperatures in excess of 30°C were prevalent, photosynthetic capacity and vegetative growth of the beds were decreased. In late fall and through winter, when temperatures averaged less than 22°C, bed thinning was very apparent and *in vitro* photosynthetic capacity declined.

Periods of increased PAR intensities at the seagrass blade level noted during spring and fall, as compared to late summer (Fig. 3), also coincide with photosynthetic rate and vegetative increases during the study. Although PAR intensities measured at the seagrass blade level (Fig. 3) are generally in excess of the amounts required for near maximal photosynthetic rates (Fig. 7), these measured levels are not always available to seagrasses. This is due to several factors including shading of seagrasses by their attached epiphytes, by phytoplankton in the overlying water column, and by adjacent seagrass blades. A study involving epiphyte productivity in eelgrass (*Zostera marina*) beds in North Carolina has shown that increased *in situ* photosynthetic rates of epiphytes, as compared to the blades to which they are attached, are due partially to shading by epiphytes (Penhale, 1977). In addition to shading, the quality of light actually reaching the seagrass blades may change due to

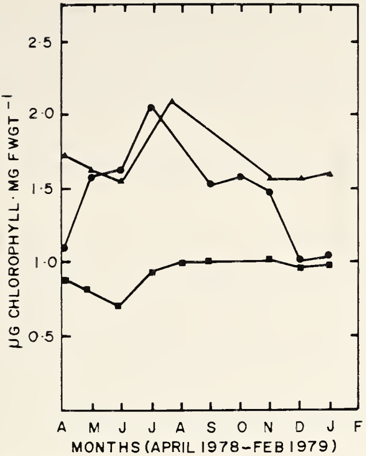

FIG. 6. Seagrass chlorophyll content (fresh weight basis) as monthly averages: *Halodule* (▲——▲) and *Syringodium* (■——■), site #2; *Halophila* (●——●), site #1.

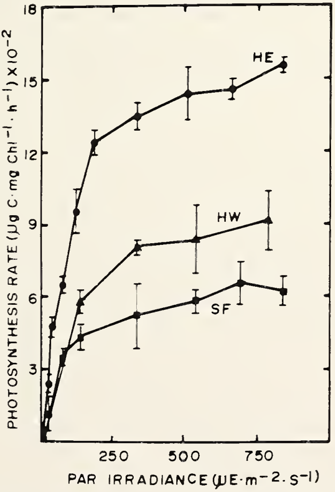

FIG. 7. Photosynthetic rate as a function of PAR intensity at 30°C: *Halophila* (●——●), *Halodule* (▲——▲), and *Syringodium* (■——■) all from site #3. Vertical lines, standard deviation; closed points, mean of 3 replicates.

selective absorption of certain wavelengths by different species of epiphytes and phytoplankton. (Russell-Hunter, 1970). Other factors affecting PAR fluctuations include increased light scattering with water depth and sediment resuspension. During summer, increasing water levels were accompanied by decreasing PAR intensities and percent light transmission (Fig. 2C) at the various sites. Sediment resuspension appears to occur throughout the year in this system: however, increased bottom disturbance, as observed during winter storms, probably contributes to the fluctuations of PAR intensities during this time of year.

Conversely, rapid sediment settling may increase PAR intensities in the water column while covering seagrass blades, thus physically restricting PAR penetration. This phenomenon appears to be more important in seagrasses with low profiles in relation to the substratum. At 2 sites, during July and August of 1977, above ground portions of *Halophila* were completely covered by sediment deposition. At site #2 sediment deposition was coincident with the building of the high rise bridge on the Melbourne causeway. Stands of *Halodule* and *Syringodium*, both with more upright profiles, appeared to be little affected by this occurrence.

Epiphyte coverage was highly variable throughout the study (Fig. 4). In addition to shading, indications are that epiphytes are in part, responsible for the extent of blade detachment in seagrass beds. Heavily epiphytic blades became necrotic and detached more readily than those with few or no epiphytes. During summer and fall of 1977 the more extensive blade detachment of *Syringodium*, which exhibited greater epiphytic densities opposed to *Halodule*, supports this observation. Although studies have shown epiphytes to be an effective shield against ultraviolet radiation (Trocine et al., 1981), the associated physical damage incurred by the attachment of epiphytes would seem to outweigh such benefits.

Seasonal trends in photosynthetic rate (Fig. 5) generally followed the observed trends of seagrass vegetative growth. Increased photosynthetic rates during spring, in conjunction with increased rhizome extension, shoot formation and blade elongation, indicate that much of the photosynthate produced is utilized for structural development of the beds.

Overall photosynthetic rates were highest in fall. However, structural development of seagrasses was reduced and primarily limited to replacement of blades lost during summer. Dawes and Lawrence (1980) have demonstrated that soluble carbohydrate levels in seagrass rhizomes increase dramatically in the fall and then gradually decline over winter. Thus, it would appear that photosynthetic products formed during the fall are primarily stored, to be utilized during times of low productivity rather than for immediate structural development.

CONCLUSION—The data obtained in this study show seagrass communities to be responsive to a variety of interrelated environmental parameters. Parameters such as temperature, light intensity and epiphyte cover may vary seasonally, while others such as sediment deposition and resuspension fluctuate continually in response to changing weather patterns and use of the system as part of the Florida east-coast inland waterway.

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TOXIC SUBSTANCE MONITORING IN THE INDIAN RIVER LAGOON, FLORIDA

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ABSTRACT: *Investigation of chlorinated pesticides and polychlorinated biphenyls (PCBs) in samples of water and sediment were made near sewage and power plant outfalls, freshwater tributaries, and agricultural runoff canals located along the Indian River between Vero Beach and St. Lucie Inlet. Chlorinated pesticide residues and PCB were not detected in surface water samples. Concentrations of several compounds such as DDT and PCB (Aroclor 1254) were low in sediment samples (< 0.1 ppm), although they were detected at least once in most samples. The persistence of malathion and parathion decreased with increasing pH and salinity. When temp was above 26°C and salinity above 20 ppt, hydrolysis was the predominant pathway of degradation of malathion and biological interaction was the most significant pathway of degradation for parathion. Industrial chemicals such as trichloroethylene and other volatile organic compounds are currently being monitored in the Main Relief Canal and Indian River at Vero Beach. Background levels of trichloroethylene were low in both water and sediment samples (< 0.1 ppb and ≅ 0.5 ppb, respectively).*

POLYCHLORINATED biphenyls and Σ DDT are ubiquitous environmental contaminants. Reports of widespread distribution of organochlorine pesticide residues in the global ecosystem are increasing (Risebrough et al., 1968; Jensen et al., 1969; Holden, 1970; Risebrough, 1972; Korte, 1976). Occurrence of organochlorines in the Indian River was investigated between Vero Beach, Indian River County, and St. Lucie Estuary, Martin County in 1977 and 1978. The Indian River is a lagoonal estuary situated along the east central coast of Florida, and extends 190 km from Titusville (Brevard County) in the north, to St. Lucie Inlet (Martin County) in the south. Figure 1 indicates approximate locations of sampling stations which were chosen between Vero Beach and Fort Pierce on the basis of proximity to major tributaries, sewage plant outfalls, or municipal areas. Surface water and sediment samples were collected and analyzed. The analytical schemes (Wang et al., 1980) for both water and sediment samples are shown in Fig. 2 and Fig. 3, respectively. Table 1 illustrates the amount of PCB and Σ DDT

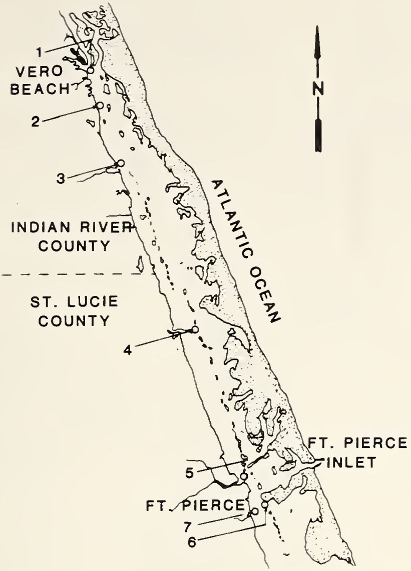

FIG. 1. Sampling sites between Vero Beach and Fort Pierce in the Indian River 1. Main Canal tributary (Vero Beach); 2. Sewage outfall (Vero Beach); 3. South Canal tributary (Vero Beach); 4. Link Port Canal (Fort Pierce); 5. Taylor Creek tributary (Fort Pierce); 6. Sewage outfall (Fort Pierce); 7. Power plant and municipal docking area (Fort Pierce).

found in sediment samples. Residues ranging from <1.0 ppb to 0.63 ppm Aroclor 1254 and from <0.1 ppb to 0.081 ppm Σ DDT were detected in most sediment samples. However, PCB and Σ DDT residues were below detection limits in water samples—less than 0.50 ppb Aroclor 1254 and 0.01 ppb Σ DDT.

Main Canal and South Canal in Indian River County are 2 major tributaries to the lagoon through which agricultural runoff occurs. Samples from the Main Canal area had slightly higher PCB and Σ DDT content than did samples from the South Canal tributary. PCB and Σ DDT residue concentrations in the Main Canal samples ranged from not detectable to 210 ppb and from not detectable to 5.62 ppb, respectively. Residue concentrations in South Canal samples ranged from not detectable to 8.67 ppb PCB and from not detectable to 0.50 ppb Σ DDT. The frequency with which PCB and DDT appeared at both sampling sites was 60%.

Taylor Creek had the highest PCB residue in the study area. Residues ranged from 20 to 630 ppb Aroclor 1254 and from 0.96 to 19.9 ppb Σ DDT. Fort Pierce Power Plant and municipal docking area also had relatively high PCB and DDT residues. Aroclor 1254 ranged from 39 to 278 ppb and Σ DDT

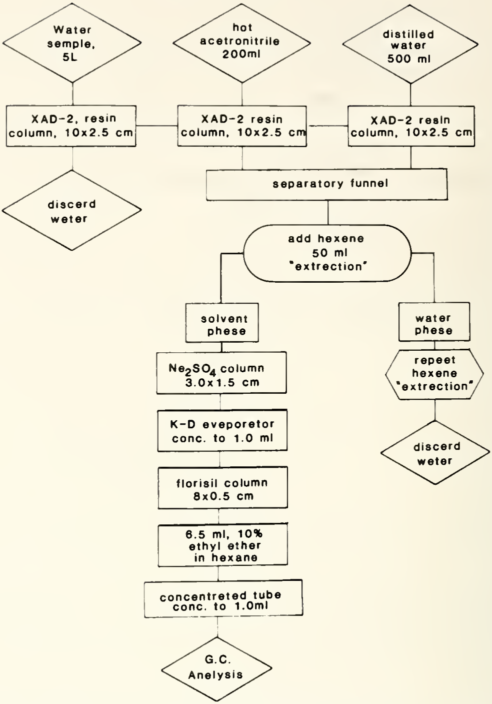
Water semple, 5L
hot acetronitrile 200ml
distilled water 500 ml
XAD-2, resin column, 10x2.5 cm
XAD-2 resin column, 10x2.5 cm
XAD-2 resin column, 10x2.5 cm
discerd weter
separatory funnel
add hexene 50 ml "extrection"
solvent phese
water phese
Ne_2SO_4 column 3.0x1.5 cm
repeet hexene "extrection"
K-D eveporetor conc. to 1.0 ml
discerd weter
florisil column 8x0.5 cm
6.5 ml, 10% ethyl ether in hexane
concentreted tube conc. to 1.0ml
G.C. Anelysis

Fig. 2. Analytical scheme for measuring chlorinated hydrocarbons in water sample (Amberlite XAD-2 Adsorption Method).

from 1.90 to 81.0 ppb in the sediment samples. Both compounds were found in all samples from Taylor Creek and Fort Pierce municipal docking areas. Samples from near the Vero Beach sewage outfall contained 1.0-16.2 ppb Aroclor 1254. Σ DDT levels ranged from not detectable to 0.38 ppb in 25% of samples. Residues in samples from near the Fort Pierce sewage outfall ranged from not detectable to 11.1 ppb Aroclor 1254 and from not detectable to 17.0 ppb Σ DDT. Five of 6 samples analyzed contained both compounds.

In 1977, polychlorinated biphenyls and DDT residues were surveyed for the St. Lucie Estuary (Wang et al., 1979). St. Lucie Estuary is a tidewater at the junction of the North and South Forks of the St. Lucie River near Stuart, Martin County, Florida (Fig. 4). The St. Lucie River flows through the Indian River and discharges through the St. Lucie Inlet. The St. Lucie Canal leaves Lake Okeechobee at Port Mayaca and extends to the South Fork of the

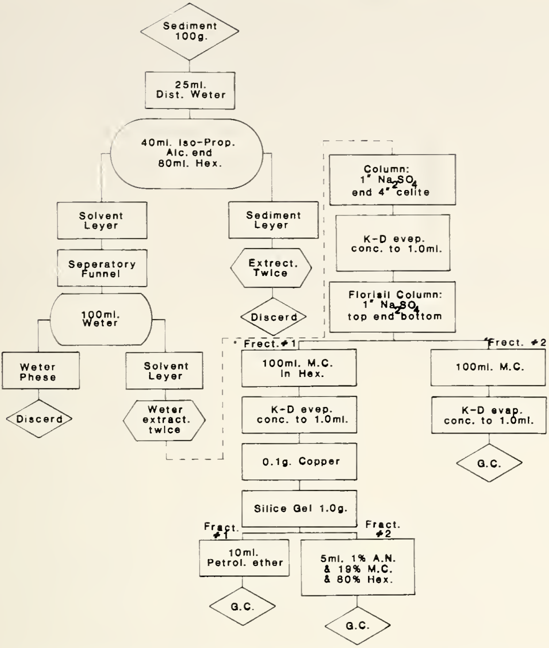

FIG. 3. Analytical scheme for measuring chlorinated hydrocarbons in sediment samples. Where Iso-prop = isopropyl alcohol, Hex = hexane, MC = methylene chloride, AN = acetonitrite and GC = gas chromatography.

St. Lucie River at Stuart. Lake Okeechobee water released through the St. Lucie Canal carries fine sand, shell fragments, and organic material into the St. Lucie Estuary. Table 2 shows residues of polychlorinated biphenyls and Σ DDT in sediment of the St. Lucie Estuary, Florida. Σ DDT levels were higher in the second and third sets of samples than in the first set. On June 20, 1977, the St. Lucie Canal discharged water from Lake Okeechobee through the St. Lucie River. The second set of samples was collected during the second da that the canal water was being discharged into the estuary. The third set of samples was collected during the last 2 da of the discharge schedule. The higher concentration of DDT compounds in the second and third sets of samples could be due to runoff from the canal. Three sets of surface water samples were also collected and analyzed. PCB and DDT were not found in the water samples.

PERSISTENCE OF MALATHION AND PARATHION—Malathion and parathion are two widely used organophosphorus insecticides in Florida Crop and

Citrus Spray Programs (EPA, 1972; Paxton et al., 1974). The residue concentrations in the Indian River depend on the persistence and degradation of both compounds in the environmental system. Chemical, physical and biological conditions could cause different degradation pathways in the estuarine systems (Bourquin, 1975; Walker, 1976; Weber, 1976; Wolfe et al., 1977). An early report (Paxton et al., 1974) indicates that malathion and parathion were not found in the Indian River system. Johnson (1978) studied the fate of both compounds in the river system.

TABLE 1. Polychlorinated biphenyls and DDT residues between Vero Beach and Fort Pierce in the Indian River Lagoon, Florida, 1977-1978. Concentration in ng/g, dry wt. PPE = p,p'-DDE, OPD = O,p'-DDD, PPD = p,p'-DDD, PPT = p,p'-DDT, DDT = DDT.

Sampling Site	Sampling Date	Aroclor 1254	PPE	OPD	PPD	PPT	DDT
Main Canal tributary (Vero Beach)	2-07-77	5.33	N.D.	N.D.	N.D.	N.D.	N.D.
	3-07-77	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	4-18-77	N.D.	N.D.	0.96	2.4	N.D.	3.36
	1-11-78	210	N.D.	N.D.	2.13	N.D.	2.13
	4-12-78	20.76	4.51	N.D.	1.11	1.97	7.59
South Canal tributary (Vero Beach)	2-07-77	8.67	N.D.	N.D.	N.D.	N.D.	N.D.
	3-07-77	1.95	N.D.	N.D.	N.D.	N.D.	N.D.
	4-18-77	N.D.	0.13	N.D.	N.D.	N.D.	0.13
	1-11-78	N.D.	0.14	N.D.	0.09	0.10	0.33
Sewage Outfall Vero Beach	2-07-77	16.2	N.D.	N.D.	N.D.	N.D.	N.D.
	3-07-77	1.36	N.D.	N.D.	N.D.	N.D.	N.D.
	4-18-77	10.1	N.D.	N.D.	N.D.	N.D.	N.D.
	4-12-78	1.0	0.17	N.D.	0.21	N.D.	0.38
Link Port (Fort Pierce)	2-07-77	23.7	N.D.	N.D.	N.D.	N.D.	N.D.
	3-07-77	2.5	N.D.	N.D.	N.D.	N.D.	N.D.
	12-15-77	N.D.	1.47	N.D.	1.80	N.D.	3.27
	1-11-78	1.89	0.07	N.D.	0.35	N.D.	0.42
	4-12-78	N.D.	0.03	N.D.	0.12	N.D.	0.15
Taylor Creek (Fort Pierce)	2-07-77	20.6	N.D.	0.96	N.D.	N.D.	0.96
	3-07-77	32.3	N.D.	7.5	N.D.	N.D.	7.5
	4-18-77	82.0	1.1	3.5	3.5	0.2	8.3
	12-15-77	41.4	13.3	5.9	0.60	N.D.	19.8
	1-11-78	570	0.50	0.50	0.91	N.D.	1.91
	4-12-78	630	6.25	5.50	0.96	N.D.	12.7
Sewage Outfall (Fort Pierce)	2-07-77	1.44	N.D.	N.D.	N.D.	N.D.	N.D.
	3-07-77	11.1	N.D.	N.D.	0.5	N.D.	0.5
	4-18-77	5.0	N.D.	0.37	1.33	N.D.	1.70
	12-05-77	N.D.	0.15	N.D.	0.38	0.06	0.59
	1-11-78	3.1	0.28	N.D.	0.36	N.D.	0.64
	4-12-78	2.21	0.14	0.26	0.79	0.06	1.25
Fort Pierce Power Plant and Municipal Docking Area	3-07-77	278	N.D.	1.9	N.D.	N.D.	1.9
	4-18-77	140	N.D.	6.2	16.5	N.D.	22.7
	12-15-77	39	13.3	5.99	33.1	28.6	80.99
	1-11-78	120	0.5	N.D.	1.00	3.20	4.70
	4-12-78	61	6.25	5.50	13.0	1.46	26.21

TABLE 2. Polychlorinated biphenyls and Σ DDT in sediments of St. Lucie Estuary, 1977. Concentration in ng/g, dry wt. AR = Arochlor 1254, PPE = p,p′-DDE, OPE = o,p′-DDE, OPD = o,p′-DDD, PPD = p,p′-DDD, PPT = p,p′-DDT, OPT = o,p′-DDT. Before = before canal discharge 14/6/77, After = after canal discharge. Dates expressed as da/mo.

Sample Number	Sampling Station Area	Detectable Compounds	Before	After	
			14/6	21/6	8/7
1	Junction of the St. Lucie River and Indian River	DDT & PCBs were non-detectable			
2	Highway A1A Bridge	AR	6.8	1.6	4.6
		PPE	0.6	0.25	0.89
		OPD	N.D.	0.56	0.20
3	Highway U.S. 1 Bridge	OPE	N.D.	0.17	N.D.
		PPE	0.09	0.29	0.31
		PPD	N.D.	0.22	0.19
4	Junction of South Fork and North Fork	OPE	-	0.53	N.D.
		PPE	-	0.18	0.53
		PPD	-	0.15	0.32
5	Bessey Creek North Fork	OPE	N.D.	0.53	N.D.
		PPD	0.2	0.73	0.16
		OPD	N.D.	0.13	N.D.
		PPD	N.D.	0.30	0.14
6	Palm City Bridge South Fork	OPE	N.D.	0.92	0.52
		PPE	N.D.	0.94	0.83
		OPD	N.D.	0.24	0.30
		PPD	1.8	0.75	1.1
		OPT	N.D.	N.D.	1.1
		PPT	N.D.	N.D.	2.3

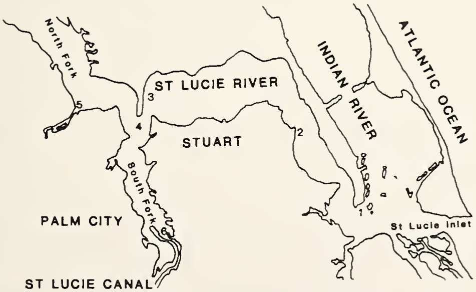

FIG. 4. Sampling stations of the St. Lucie Estuary. 1. Junction of the St. Lucie River and the Indian River; 2. Highway A1A Bridge; 3. Highway U.S. 1 Bridge; 4. Junction of South Fork and North Fork; 5. Bessey Creek, North Fork; 6. Palm City Bridge, South Fork.

Malathion degradation is regulated by the pH concentration of the water and undergoes alkaline hydrolysis as shown in Fig. 5. When salinity is at 24 ppt, a twofold hydrolysis rate increase occurs from pH 6.0 to 7.0. From pH 7.0 to 8.16, it is a twelvefold rate increase. The hydrolysis rate is also dependent on the salinity of water. Persistence of malathion is inversely related to salinity (Weber, 1976; Johnson, 1978). At pH 6.0 and a salinity of 24 ppt, malathion persists for longer than 30 da. When the river water is at pH 7.0 and a salinity of 24 ppt, the persistence time decreases to approximately 7% after 30 da. These times continue to fall rapidly as the pH and salinity of the water rise. In water of pH 8 and salinity of 25-35 ppt, which is normal for the river, malathion degrades completely within 12 da. Parathion undergoes alkaline hydrolysis, but unlike malathion, it is not the predominant degradation pathway. As can be seen from Fig. 6, the most competitive way is due to biological interaction. In synthetically prepared solutions, the half-life of parathion in non-sterilized river water is less than approximately 12 da, and for sterilized water is more than 30 da. The persistence of parathion is also decreased with increasing salinity (Weber, 1976; Johnson, 1978). In Indian River open water of pH 8.16 and salinity of 24 ppt, the concentrations of parathion are 50% degraded within 10 da and 94% in 30 da.

Hydrogen ion concentration, temperature, salinity, and microorganisms affect the persistence of both malathion and parathion in the Indian River System. Water bodies near freshwater tributaries and mangrove areas with lower pH values and salinities have longer persistence times. With pH 6.0 to 6.5 and salinity of 10 to 15 ppt, malathion will be quite persistent even after 30 da. Parathion will degrade slightly faster due to biological interaction. Nearer the inlets, pH and salinity will both increase considerably. At pH 8.0 to 8.5 and salinity of 30 to 35 ppt, malathion and parathion will completely degrade in approximately 4 and 30 da, respectively.

TRICHLOROETHYLENE RESIDUE IN THE MAIN RELIEF CANAL AND THE INDIAN RIVER AT VERO BEACH — Trichloroethylene (trichloroethylene), $CCl_2 = CHCl$ is used primarily in metal degreasing, dry cleaning operations and as a solvent in organic synthesis. A recent study (Wang, 1980) indicated that trichloroethylene has contaminated underground water in the Indian River County. Contaminated ground water was being pumped out, sprayed , and aerated before being discharged into the Main Canal and the Indian River at Vero Beach. A monitoring program was established to determine the baseline level and the impact of trichloroethylene in the canal. Water, sediment and invertebrate samples were collected and analyzed. The results indicate that the background level of trichloroethylene residue in water, sediment and oyster samples between April 14, 1980 to November 18, 1980 were less than 0.1 $\mu g/\iota$, 0.5 ng/g and 1.0 ng/g, respectively (Wang, 1980). These levels are being used to assess the impact of trichloroethylene contaminated groundwater discharge to the Main Relief Canal and Indian River at Vero Beach, Florida.

CONCLUSIONS — Low concentrations of PCBs and Σ DDT residues were

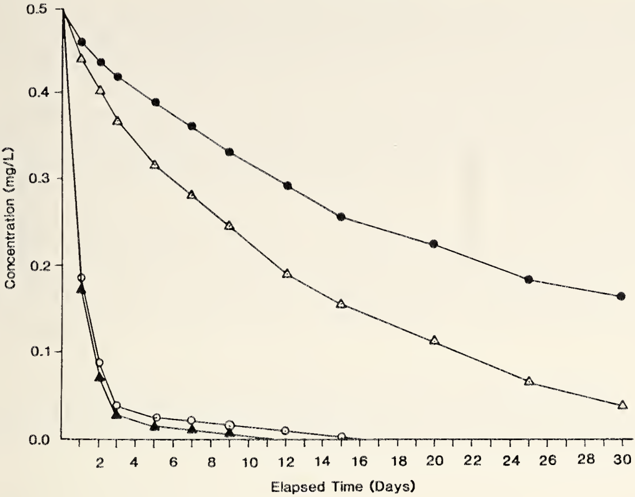

FIG. 5. Degradation of Malathion in river water at different pH (salinity at 24 ppt). ● = pH 6.0; △ = pH 7.0; ○ = pH 8.06; ▲ = pH 8.16 (dark bottle); Temperature 28°C; Salinity 24 ppt.

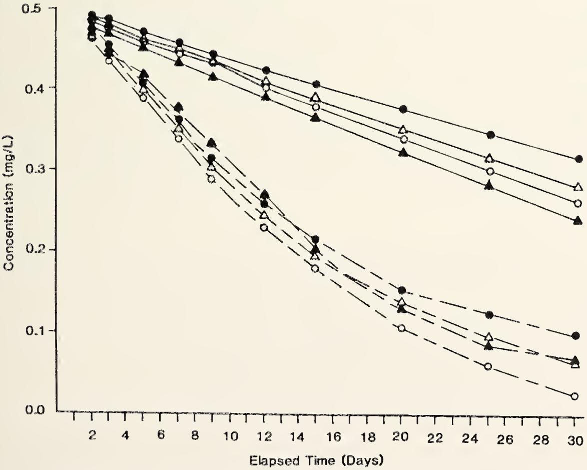

FIG. 6. Degradation of Parathion in river water at different pH. ● = pH 6.0; △ = pH 7.0; ○ = pH 8.16; ▲ = pH 8.16 (dark) ———— Sterile River Water; — — — Non-sterile River Water; Temperature 28°C; Salinity 24 ppt.

found only in the sediment samples. Sediment samples collected from Taylor Creek tributaries and Fort Pierce municipal docking area had higher PCB and Σ DDT residue levels than did other sample sites. The source of the compounds is not known.

Concentrations of malathion and parathion were non-detectable in the river. The persistence of both compounds decreased with increasing pH and salinity. When the temperature was about 28°C and salinity was more than 20 ppt, hydrolysis was the predominant pathway of degradation for malathion and biological interaction was the most significant pathway of degradation for parathion. Industrial chemicals such as trichloroethylene were low in both water and sediment samples in the initial background level. The residue concentration of pollutants could vary with runoff, rainfall, water temperature, tidal flushing, and wind-drawn circulation in the river.

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A COMPARISON OF PRIMARY PRODUCTION RATES IN INDIAN RIVER, FLORIDA SEAGRASS SYSTEMS

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Abstract: *Three sites in the Indian River, Florida were studied to determine primary production in seagrass meadows. Production rates were obtained for 3 species of seagrasses* (Thalassia testudinum, Syringodium filiforme *and* Halodule wrightii), *associated epiphytic flora, benthic microalgae and phytoplankton. Photosynthetic rates for Indian River seagrasses in March and July ranged between 0.009-0.395 mg C/g dry wt-h for* H. wrightii, *0.005-0.79 for* T. testudinum, *and 0.009-1.72 for* S. filiforme. *Epiphytic productivity per g dry wt varied considerably between stations and from season to season. Productivity maxima for* H. wrightii *and* S. filiforme *occurred at the Jim Island station;* Thalassia testudinum *demonstrated maximum photosynthetic response at Link Port. Phytoplankton, benthic microalgae and epiphytic production were similar at each station and increased slightly from March to July. However, their absolute importance in community productivity changed dramatically depending upon the contribution of the seagrass species.*

The Indian River is a broad, shallow coastal lagoon which harbors dense populations of seagrasses. It has been estimated that seagrasses cover 2% (2776 ha) of the river bottom between Merritt Island and the St. Lucie Inlet (Thompson, 1978). Of the 20 known seagrass species, 6 occur in the Indian River (Eiseman, 1980): *Halodule wrightii* Aschersen, *Thalassia testudinum* Banks ex Konig et Sims, *Syringodium filiforme* Kutzing, *Ruppia maritima* Linnaeus, *Halophila englemanii* Ascherson and *Halophila johnsonii* Eiseman. *Halodule wrightii, S. filiforme* and *T. testudinum* are the most abundant (Thompson, 1978).

Primary production is considered the most essential function of a seagrass meadow, and as a result, seagrass ecosystems support rich communities of plants and animals (McRoy, 1974; Topham et al, 1974; Thayer et al., 1975;

McRoy and McMillan, 1977; Jacobs, 1977. The role of seagrasses in coastal ecosystems has been summarized by Wood et al. (1969), Zieman and Wetzel (1974) and Topham et al. (1975). Because seagrasses are highly visible and most often the dominant primary producer, other autotrophic components of the community are often neglected. These include epiphytic algae, benthic microalgae and phytoplankton.

The number of *in situ* productivity studies on seagrass communities is small, and to our knowledge no single study has considered the contribution of the various primary producers to the total productivity in a seagrass meadow. The objects of this study were to determine the primary production rates of the 3 principal seagrasses in the Indian River and to investigate the contribution of seagrass epiphytes, benthic microalgae and phytoplankton to the total productivity in a seagrass meadow. At present, comparable information is not available on primary production of Indian River seagrasses. It is becoming increasingly important to obtain such information because Florida coastal areas are threatened by urban and industrial development.

Drift algal productivity was not considered in this study. The extent and persistence of large drift algal populations in the Indian River suggest that they are an important part of the total ecosystem (Eiseman & Benz, 1975; Gilmore, 1976; Thompson, 1978). However problems associated with 1) productivity measurements for a wide variety of algal species and 2) estimating drift algal biomass were beyond the scope of this study and the object of a separate study currently in progress (R. W. Virnstein, pers. comm.).

LOCATION AND METHODS—The study area encompassed a 25 km section of the Indian River from the Ft. Pierce Inlet to the City of Vero Beach, Florida (Fig. 1). Three grassbed stations (from south to north) referred to as Jim Island, Link Port and Vero Beach were chosen to represent distinctly different physical-chemical environments. The Vero Beach station was located 6 km north of the City of Vero Beach at channel marker 118 on the west side of a spoil bank. The site was situated 25 km north of the Ft. Pierce Inlet and 25 km south of the Sebastian Inlet and was chosen as an area influenced primarily by land runoff and land-use practices. The area was characterized by salinities less than 32 ppt (annual average), high nutrient levels, wide temperature variations and minimal water movements (Table 1). Current velocities ranged between 9.0-15.0 cm/sec for a lunar cycle (M. Sternberger, pers. comm.), or approximately 30% of those at the Ft. Pierce Inlet. Tidal currents at this station are less significant in the net displacement of water due to the increased distance from the ocean inlets. Seagrass beds at Vero Beach are dominated by *H. wrightii* intermixed with sparse beds of *T. testudinum*. *Syringodium filiforme* was not found at this station. The Link Port station was located on the north side of the north spoil finger of Link Port channel, 9 km north of the Ft. Pierce Inlet. Link Port has physical-chemical characteristics intermediate between the Vero Beach and Jim Island stations (Table 1). The area is influenced to some extent by the salt wedge from the Ft. Pierce Inlet. *Halodule wrightii*, *S. filiforme* and *T. testudinum* occur consistently at this station. Grassbeds at Jim Island were chosen to represent an area influenced primarily by oceanic processes. The sampling site was a broad grassflat on the south side of the north bridge causeway near the Ft. Pierce Inlet. The grassflat is characterized by wide tidal fluctuations and maximal water movement. Current velocities range between 31.6-48.7 cm/sec for a lunar cycle (M. Sternberger, pers. comm.). Relatively low nutrient, high salinity oceanic water covers the area most of the time (Table 1). Water temperatures and salinities are more stable and fluctuate less than at the Vero Beach station. All 3 seagrasses were abundant at this station.

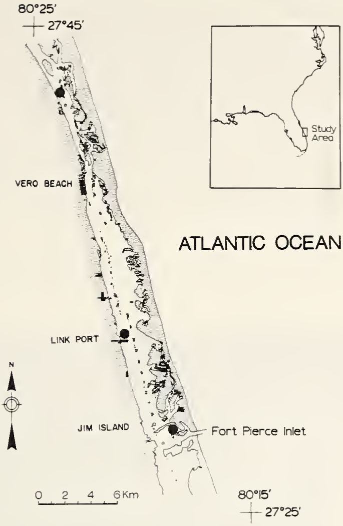

FIG. 1. Location of the study sites in the Indian River, Florida.

All productivity estimates were determined using radiocarbon techniques. Although use of ^{14}C in seagrass production measurements has recently been criticized due to possible internal recycling of CO_2 (Patriquin, 1973; Wetzel and Hough, 1973; McRoy, 1974) it remains the method of choice due to its high sensitivity, short incubation times, compatability with other autotrophic components and applicability to all seagrasses.

To obtain comparable data from the different components, productivity measurements must be performed under similar environmental conditions. An *in situ* incubation chamber was designed which allowed simultaneous measurements of phytoplankton, seagrass and epiphytic algal production (Fig. 2). The seagrass short shoot was inserted through the bottom of the chamber and sealed from the surrounding environment with non-porous neoprene rubber. By this method the short shoot remained intact *in situ*. A Savonius rotor was attached to the top of the incubation chamber (20 cm high, 4 cm ID) and coupled to an inner tube with magnets. Currents in the surrounding environment turn the Savonius rotor as well as the inner tube to insure constant mixing inside the chamber. Using a flow tank and measured flow rates it was possible to demonstrate that the incubation chamber was 85-90% efficient in imitating the current regime outside the chamber. Light transmission, as measured with a Biospherical Instruments PSL-10 Light Meter, was reduced 15% inside the chamber. Productivity levels were adjusted accordingly, assuming linearity between productivity and light energy levels below saturation. Such linearity has been noted for *T. testudinum* (Bittaker and Iverson, 1976) and *Zostera marina* (Dillon, 1974) and we have assumed linearity for *H. wrightii* and *S. filiforme*.

Triplicate 3-hr incubations were made on individual short shoots for each seagrass species. Each chamber was injected with 1.0 ml of 10-15 μCi of $NaHC^{14}O_3$. Incubations were made between 1000 and 1300 h. Each site was sampled in the spring (March) and summer (July) of 1981. After incubation, the chamber with short shoot was removed from the sediment. The chamber water was filtered onto 0.4 μm Nucleopore filters for determination of phytoplankton productivity. To remove any unincorporated ^{14}C, 0.5 ml of 0.5N HCL was added to each filter and allowed to evaporate (Williams et al., 1974). After each filter was digested with 1.0 ml of NCS tissue solubilizer (Amersham Corp.), 10 ml of scintillation cocktail (ACS-Amersham Corp.: toluene:water — 7:3:1) was added and the sample counted using a Searle Mark III LSC with ESR

TABLE 1. Physical and chemical characteristics of the three sampling sites. Values represent weekly measurements of a 2.5 yr study from January, 1976 through June, 1978 (Indian River Coastal Zone Study, M. J. Youngbluth, pers. comm.). Temperature of surface water is in °C; Salinity in ppt and the nutrient concentration unit is micromolar.

	Vero Beach			Link Port			Jim Island		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Temperature	10.5	31.6	23.7	10.0	31.0	23.1	12.5	29.0	23.1
Salinity	15.0	37.0	28.0	18.1	37.5	30.8	27.0	37.0	34.5
Silicate	8.2	354.0	36.5	2.6	268.4	26.2	0.6	29.8	7.1
Phosphate	0.3	6.1	1.3	0.1	3.5	0.9	0.1	6.0	0.4
Nitrate	0.1	83.6	2.6	0.1	63.3	1.4	0.1	51.8	1.1
Ammonia	0.3	31.0	4.4	0.3	19.7	2.7	0.3	8.1	1.9

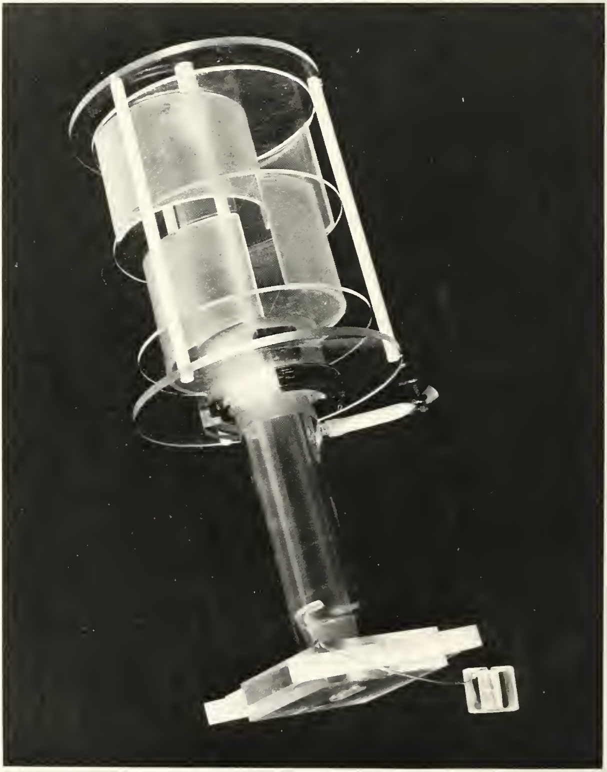

FIG. 2. *In situ* incubation chamber used to determine seagrass productivity.

counting techniques at 85-90% efficiency. The seagrass short shoot was quick frozen in a dry ice/acetone slurry. Epiphytes were separated from the seagrass blade using the freeze-drying technique of Penhale (1977). Solubilization of the seagrasses and epiphytes followed a modification of the methods of Gagne et al. (1979). Each sample was ground to a powder using a "wiggle bug" grinder (Crescent Dental Manufacturing Co.). One-half ml of 30% H_2O_2 was added to 5-10.0 mg of plant tissue. Vials were capped and placed in an oven at 50°C for 24 h. One ml of NCS was then added and the vial reheated at 50°C for approximately 3 hr. After cooling, cocktail was added and the sample counted as before.

To determine solubilization efficiency, non-labeled freeze-dried seagrasses were ground to a powder. Approximately 9000 DPMs of sucrose ^{14}C was added to the powder as an internal standard. The sample was digested and counted. The solubilization technique was 100 ± 2.5% efficient in recovering labeled ^{14}C (Table 2).

TABLE 2. Recovery of ^{14}C from seagrasses and epiphytes of known radioactivity using the solubilization technique (Weight in mg).

Species	N	Weight	% Recovery
Thalassia testudinum	6	25-64	99±2.4
Syringodium filiforme	5	19-52	98±2.7
Halodule wrightii	4	18-37	101±2.5
Epiphytes	6	20-56	98±2.4

Productivity of benthic microalgae was determined for the upper 2.5 cm of sediment. Sediment cores (2.0 cm ID) were taken in the grassbeds and one ml of $NaHC^{14}O_3$ (10-15 μCi) was injected into each corer. The corer was capped and returned to the grassbed for 3 hr. The water was decanted from the sampler and the sediments immediately extracted and frozen. Productivity was determined using a modification of the method of Van Raalte et al. (1974). Unlabeled ^{14}C was removed from the sediment by washing with 2N HCL. The sediment was centrifuged (10,000 RPMS) and the supernatant discarded. The sample was then digested for 12 h with 10 ml of concentrated HNO_3. After centrifugation (10,000 RPMS), 1 ml of supernatant was buffered with 9 ml of 0.75 M Tris buffer. One ml of buffered sample was added to 10 ml of cocktail and counted. Van Raalte et al. (1974) recovered 94-98% of algal-fixed ^{14}C using this acid digestion method. They also found little variation in percent recovery between sandy and fine organic mud sediments.

Seagrass biomass was determined using a modified post-hole digger (Indian River Coastal Zone Study Annual Report, 1974-1975: 92). Three replicate seagrass plugs, 15 x 15 cm and 20 cm deep, were made at each station for each species. Sampling was stratified, i.e., an area with maximum *Halodule* cover was chosen to sample biomass of that grass assuming this to represent the maximum production potential of the locality with respect to this species. These plugs were also used to determine epiphytic biomass. This was determined by finding mean epiphytic biomass of 9-12 seagrass blades and converting to an areal basis by a determination of the number of seagrass blades per m^2.

RESULTS AND DISCUSSION — Table 3 shows seagrass and epiphyte productivity (mg C/g dry wt-h) at the three sampling sites in March and July, 1981. Primary production of both components was low during March (<0.1 mg C/g dry wt-h) but increased 1-3 fold in July. Epiphytic production ranged between 0.003 mg C/g dry wt-h in March to 1.02 in July. Penhale (1977) found a similar response of epiphytic algae on *Zostera* leaves. Over a 12 mo period the productivity rate of *Zostera* epiphytes averaged 0.88 mg C/g dry wt-h. Data in Table 3 show that the photosynthetic response of epiphytes can equal or exceed that of seagrasses. Epiphytic productivity is highly dependent upon the composition of the epiphytic community. If large animal biomass is present, especially species with calcified exoskeletons, the result is an underestimation of photosynthetic rate on an areal basis and

TABLE 3. Seagrass and epiphyte productivity of the above ground portions at various locations. The data represent mean values in mg C/g dry wt-h. Percent relative standard deviations are in parenthesis. Asterisk indicates only enough material for 1 sample.

Station	Jim Island		Link Port		Vero Beach
Date	March	July	March	July	July
Halodule wrightii	1.0 10^{-2} (48.5)	0.40 (90.3)	8.6 10^{-3} (15.5)	0.36 (22.7)	0.29 (102.7)
Epiphytes	8.36 10^{-3} (117.5)	0.17 (94.2)	1.0 10^{-2} (138.6)	0.30 (8.9)	0.09 (71.7)
Thalassia testudinum	5.42 10^{-4} (10.18)	0.32 (41.3)	5.42 10^{-3} (4.5)	0.79 (44.8)	0.09 (80.6)
Epiphytes	1.39 10^{-3}(*)	0.64 (137.4)	5.58 10^{-3} (47.5)	0.75 (49.6)	0.33 (138.0)
Syringodium filiforme	9.2 10^{-2} (138.3)	1.72 (96.1)	9.82 10^{-4} (5.1)	0.46 (16.7)	———
Epiphytes	5.4 10^{-2} (132.3)	0.52 (81.0)	9.3 10^{-3} (139.8)	1.02 (103.2)	———

overestimation on a gravimetric basis. *Thalassia testudinum*, with its broad leaf, is an especially good substrate for foraminiferans, bryozoans and other animal species. Estimates of epiphytic productivity is, therefore, more subject to error on this species than *H. wrightii* and *S. filiforme*. Until methods are devised to adequately separate epifaunal and epifloral biomass, true epiphytic photosynthetic rates and contribution to community productivity cannot be determined.

TABLE 4. Changes in seagrass standing crop (g dry wt/m²) from March to July, 1981 at each sampling site.

Station	Jim Island		Link Port		Vero Beach
Date	March	July	March	July	July
Halodule wrightii	123.5	197.6	20.4	72.0	45.0
Thalassia testudinum	64.3	124.0	97.9	160.3	85.0
Syringodium filiforme	19.1	11.9	48.8	57.7	0.0

On a g dry wt basis, *Syringodium filiforme* demonstrated the highest productivity rates of all 3 species in both March (0.09 mg C/g dry wt-h) and July (1.72) at Jim Island (Table 3). During this study, ranges in photosynthetic rates for Indian River seagrasses were 0.009-0.395 mg C/g dry wt-h for *H. wrightii*, 0.005-0.79 for *T. testudinum* and 0.009-1.72 for *S. filiforme*. No comparable data are available on *Syringodium* production rates, however, carbon uptake rates for *T. testudinum* and *H. wrightii* have been measured elsewhere at 0.13-6.3 and 1.8 mg C/g dry wt-h respectively (Pomeroy, 1960; Odum, 1963; Jones, 1968; Brylinsky, 1971).

Table 4 shows seagrass biomass values exclusive of epiphytes. At Jim Island and Link Port the standing crop of *H. wrightii* and *T. testudinum* increased at least 60% from March to July while *S. filiforme* showed constant values. *Halodule wrightii* had the highest standing crop values at Jim Island, *T. testudinum* at Link Port and Vero Beach, and *S. filiforme* the lowest values at all 3 stations. These trends held true for both sampling periods within the sampling sites.

The contribution of various photosynthetic components at each station is shown in Table 5. Seagrasses appear to be the dominant autotrophic component in July and benthic microalgae dominant in March. Productivity rates (mg C/m²-h) for *Halodule* and *Syringodium* were highest at Jim Island during both sampling periods. *Thalassia*, on the other hand, showed the highest rates at Link Port. Although *S. filiforme* weight-specific production rates were the highest measured (Table 3), the standing crop of this species was the lowest (Table 4) which accounts for its low areal production.

Epiphytic productivity varies considerably between stations and from season to season (Table 5). As stated previously, this variation may be a result of the incrustation of various epifauna. Epiphytic populations can vary considerably within the year, the growing season and among short

TABLE 5. Contribution of the various photosynthetic components at each sampling location during the spring and summer of 1981. Values are mg C/m^2-h^1 and represent the means of 3 seagrass and epiphyte replicates, 4 benthic microalgae replicates and 6 phytoplankton replicates. Percent relative standard deviations are in parenthesis. Asterisk indicates only enough material for 1 sample.

Station	Jim Island		Link Port		Vero Beach
Date	March	July	March	July	July
Halodule wrightii	1.22 (43.5)	47.00 (50.1)	0.18 (14.8)	2.63 (19.8)	13.15 (102.7)
Epiphytes	0.56 (36.3)	8.75 (55.3)	1.00 (138.9)	2.46 (26.9)	0.40 (116.1)
Thalassia testudinum	0.04 (10.4)	30.30 (94.7)	1.32 (4.4)	128.1 (44.9)	8.39 (80.6)
Epiphytes	0.05 (*)	0.42 (135.1)	1.94 (0.0)	0.70 (52.1)	0.32 (131.6)
Syringodium filiforme	1.75 (138.29)	20.4 (96.18)	0.05 (6.0)	2.66 (18.8)	——
Epiphytes	0.28 (138.8)	0.32 (41.85)	0.12 (155.1)	0.11 (83.8)	——
Benthic microalgae	1.66 (22.9)	3.30 (21.5)	33.8 (24.2)	28.9 (23.6)	15.0 (19.2)
Phytoplankton	0.21 (20.6)	2.48 (19.0)	1.43 (51.5)	2.99 (20.0)	7.22 (4.9)

shoots (Brown, 1962; Hargrave, 1965). Epiphytic productivity rates on Indian River seagrasses ranged from 0.5-8.75 mg C/m²-h. These values are considerably less than the 200-900 mg C/m²-h reported by Jones (1968) for epiphytes on *Thalassia* in Biscayne Bay, Florida. However, production rates of Indian River seagrass epiphytes on a wt specific basis (Table 3) are comparable to other seagrass systems (see Penhale, 1977).

Benthic microalgae contribute significantly to community productivity in Indian River seagrass beds. During March this fraction accounted for 89-95% of the primary productivity within the various seagrass beds at Jim Island and Link Port (Table 5). During July this group was the largest contributing component in Vero Beach grassbeds. Benthic microalgae had a greater impact on primary productivity at Link Port and Vero Beach than at Jim Island. Sites farther from ocean inlets (i.e., Link Port and Vero Beach) typically have reduced light regimes and current velocities. Sediment microflora proliferate in shallow, sluggish backwater areas with little water movement, high nutrient concentrations and poor light regimes, and may actually be adapted to seemingly stressful conditions (Round, 1971; Jones, 1980). Vero Beach and Link Port more closely satisfy these conditions than Jim Island which characteristically exhibits high flushing rates, low nutrient concentrations (Table 1) and high light penetration.

Phytoplankton had their greatest productivity rates and contribution to overall community production in July at Vero Beach. Phytoplankton values were also higher at Link Port than Jim Island. Though the number of sampling periods was limited, this agrees with trends of chlorophyll a, phytoplankton cell abundance and productivity measurements taken during the Indian River Coastal Zone Study (Gibson, unpubl. data). Weekly measurements of these parameters from 1976 through 1978 showed values consistently highest at Vero Beach, lowest at Jim Island and intermediate at Link Port.

Of the photosynthetic components shown in Table 5, phytoplankton and epiphytic algae contribute the least to community productivity. The phytoplankton population appears to play a more important role farther from the ocean inlet (Jim Island) which may be a reflection of increased nutrient concentrations at Vero Beach (Table 1). Seagrass and benthic microalgae were the dominant primary producers of the system during the study period. However, the changes in seagrass productivity account for most of the variation in production in the grass meadows. The other components were either relatively stable or relatively low in their photosynthetic rates.

The summer period (May-September) appears to encompass the time span of maximum seagrass growth in the Indian River. Table 6 provides the salinity and temperature data for this time period. Seagrass productivity is regulated in a complex manner by environmental factors such as light, temperature and salinity. Studies have shown the optimum temperature for seagrass growth to be near 29°C and sublethal temperatures (i.e., low pro-

TABLE 6. Mean and standard deviation of integrated water column salinity and surface temperatures from May through September in 1976 and 1977. Values were compiled from weekly measurements taken during the Indian River Coastal Zone Study (M. J. Youngbluth, pers. comm.).

Station	Jim Island		Link Port		Vero Beach	
Date	1976	1977	1976	1977	1976	1977
Integrated Salinity (ppt)	22.1 ±4.24	28.9 ±4.6	26.9 ±4.75	33.6 ±2.57	32.64 ±2.46	35.6 ±2.13
Surface Temperature (°C)	29.5 ±1.52	29.1 ±1.75	28.3 ±0.88	28.01 ±1.29	26.5 ±1.56	26.7 ±1.24

ductivity) between 29-32°C (Zieman, 1968; Thorhaug, 1971; Zieman and Wetzel, 1980; Zieman, 1975). Salinity tolerances are more broad, yet there is a definite optimum between 33-36 ppt (Jones, 1968; McMahan, 1968; McMillan and Moseley, 1969; Zieman and Wetzel, 1974; Zieman, 1975). It is apparent from Table 6 that Jim Island and Link Port offer the best conditions for seagrass growth in this section of the Indian River. Water temperatures and salinities at Vero Beach are not at optimum levels which is reflected in the reduced biomass and productivity of the seagrasses. Thompson (1979) felt the reduced salinities, increased temperatures and reduced light levels (caused by tannins from the freshwater runoff) were partially responsible for the poor conditions of the grassbeds in the Vero Beach area.

Seagrass production is likely to be very significant in supporting foodwebs in the Indian River (Young, 1976; Zimmerman et al., 1979; Stoner, 1980a, 1980b). Our estimates indicate that seagrass communities may contribute a major portion of the total primary production in the River. While the seagrass species may be the driving component of the system it is only one of many primary producers. The influence of the phytoplankton, benthic microalgae and epiphytes must be examined if the total productivity of the system is to be determined. Other plant communities such as mangroves, salt marshes, algal mats and drift algae are also important and should be examined as well.

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A CHECK-LIST OF THE BENTHIC MACROINVERTEBRATES OF KENNEDY SPACE CENTER, FLORIDA

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Abstract: *A quarterly baseline study of benthic macroinvertebrates was conducted from December 1979 to March 1981 in the brackish lagoons surrounding Launch Complex 39A (LC-39A) of the John F. Kennedy Space Center. This was performed as part of the NASA Environmental Effects Program for Space Shuttle activities. A baseline monitoring study was also conducted in the Banana River from December 1979 to December 1980 to monitor benthic community recovery at 2 sites in the Banana River following removal of silt by shallow water dredging. A check-list of the macroinvertebrates found in the 2 areas is given. One hundred and twenty-two species were collected from both studies: 67 species from the lagoons and 108 species from the Banana River; 53 species were common to both areas.*

A Marine Benthic Program was initiated by NASA at the John F. Kennedy Space Center, Florida, in August 1979 for 2 purposes: 1) to establish a baseline of pre-Shuttle operation conditions in the lagoons surrounding Launch Complex 39A (LC-39A) to ascertain possible adverse impact of Shuttle launch activities, and 2) to monitor benthic community recovery at 2 sites in the Banana River following removal if silt by shallow water dredging. The lagoon baseline study was conducted from December 1979 to March 1981 (the first Shuttle launch occurred 12 April 1981). The Banana River siltation recovery study was conducted from December 1979 to December 1980.

While no previous benthic studies have occurred in the lagoonal waters adjacent to LC-39A or the upper Banana River, studies have been conducted in the Indian River, and the lower Banana River, Brevard County. Studies have included those by Clark et al. (1975), Young and Young (1977), Young et al. (1976), and Grizzle (1974, 1979). The Harbor Branch Foundation of Ft. Pierce, Florida has extensively sampled the Indian River System including Mosquito Lagoon. A benthic study was conducted by Applied Biology, Inc. of Decatur, Georgia for the Florida Power & Light Co. and the Orlando Utilities Commission, from July 1978 to November 1979 in the Indian River, to assess the impact of the heated effluents. Over 400 quarterly benthic samples were collected from an area between 0.5 mi north of NASA Causeway to 0.5 mi south of Highway 528. The Brevard County Health Department frequently samples benthic populations in various areas of the Indian and Banana Rivers.

Description of Study Area — Surface waters surrounding the Kennedy Space Center consist of Mosquito Lagoon, Indian River, Banana River, and Banana Creek with numerous man-made canals and impoundments occurring throughout the Center. The Indian and Banana rivers are wind-driven brackish water lagoons with very little or no tidal action. The 2 rivers are separated by Merritt Island in the northern portions but join in the vicinity of Melbourne to the south. Prior to the construction of LC-39A and B, the rivers were joined to the north by Banana Creek. The northern terminus of the Indian River is connected to Mosquito Lagoon by Haulover Canal. In Brevard County, the Indian River connects to the Atlantic Ocean to the south through Sebastian Inlet. The Banana River is connected to the Atlantic through the lock at Port Canaveral.

LC-39A is located at the very northern tip of the Banana River and currently is the primary launch pad for the Space Shuttle (previous launches had occurred on this pad prior to the Shuttle Program). The launch complex is surrounded to the north by wetlands and a series of wind-driven brackish water lagoons; 2 of which, Lagoon 1 and Gator Hole (Fig. 1), were sampled as part of the NASA Environmental Effects Program for Space Shuttle activities. These lagoons are connected to the northern part of the Banana River by a culvert located to the east of the pad.

Ten stations were selected for the lagoon sampling; 9 located in Lagoon 1 and Gator Hole, and 1 located at the very northern portion of Banana River (Fig. 1). Lagoon 1 and Gator Hole are predominantly shallow water; however, Gator Hole contains a dredged area with certain parts averaging a depth of 9 m (Stations 8 and 9). The deepest area in Lagoon 1, Station 7, was 2.2 m. Stations 1 through 6 averaged depths of 33 cm. to 62 cm. Water temperatures in the 2 lagoons ranged from a low of 19°C in December 1979 to a high of 32°C in July 1980. Salinity averaged 20 ppt. Sediment was predominantly fine sand shell and mud at Stations 1, 3, 5, 6 and 7; silt at Station 8 and 9; and soft clay at Station 4. Chemical analyses of the water and sediments are available. Little or no vegetation occurred at the 9 stations.

Four stations were selected in the Banana River for benthic sampling.

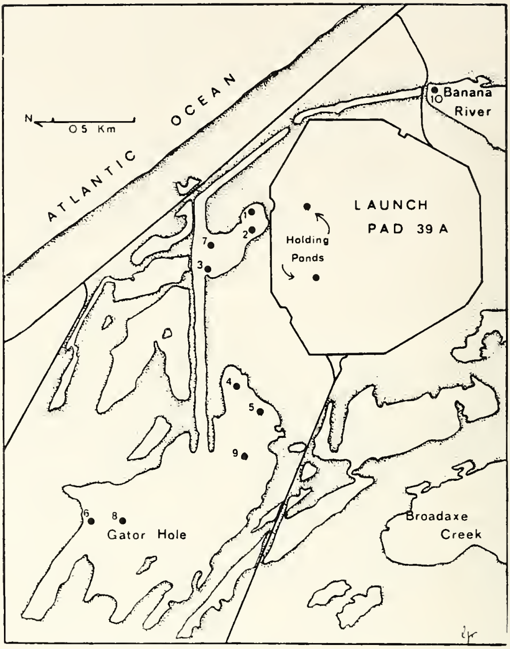

FIG. 1. Location of launch pad 39A and sampling sites.

Stations 11, 12, 13, and 14 are 8.5, 12.0, 16.5, and 21.0 km. south of Station 10, respectively. Stations 11 and 14 were located in the 2 silt problem areas. All stations were shallow averaging 33 cm. to 51 cm. in depth. Water temperatures ranged from 17°C to 32°C during the year, and salinity averaged 24 ppt. Sediment was predominantly composed of sand and crushed shell at Stations 10, 12, and 13; Station 11 was similar, but mixed with mud and silt; and Station 14 contained silt. Shoal grass *(Halodule wrightii)*, manatee grass *(Syringodium filiforme)*, and *Gracilaria* sp. was present at all stations except 14.

METHODS—Benthic stations were sampled quarterly. Three replicate benthic grabs were taken with an ECKMAN GRAB (15.24 cm. x 15.24 cm. x 15.24 cm.) at each station. The samples were field-washed through a 0.5 mm. sieve. The collected material was then placed in 10% buffered formalin for 48 to 72 hr, transferred to 70% isopropyl alcohol, sorted, and identified.

RESULTS—The species collected from the lagoons surrounding Launch Complex 39A and those collected from the Banana River are in Table 1. One hundred and twenty-two species were collected. Of this total, 67 species were from the lagoons and 108 species from the Banana River; 53 species were common to both areas.

Table 1. The following is a systematic check-list of the marine invertebrates collected from the lagoons surrounding Launch Complex 39A and the Banana River from December 1979 through June 1981. LS indicates lagoon system; BR indicates Banana River. Asterisk indicates species previously reported from the Indian and Banana Rivers. Subscript 1 indicates new reports.

SPECIES	LS	BR
Phylum COELENTERATA (Cnidaria)		
Cnidaria unid.	x	x
Actiniaria unid.	x	x
Phylum PLATYHELMINTHES (Flatworms)		
Platyhelminthes unid.	x	x
Phylum NEMERTINA (RHYNCHOCOELA)		
Nemertina unid.	x	x
Phylum NEMATODA		
Nematoda unid.	x	x
Phylum ECTOPROCTA (BYROZOA)		
Ectoprocta unid.		x
Phylum PHORONIDA		
Phoronis sp.	x	x
Phylum MOLLUSCA		
Class Gastropoda		
Acteocina canaliculata	x	x*
Acteon punctostriatus		x*
Bermudaclis tampaensis		x*
Caecum cooperi		x*
Caecum pulchellum	x	x*
Cerithium muscarum		x*
Cerithium sp.		x
Crepidula maculosa[1]	x	x
Crepidula sp.		x
Crepidulidae unid.		x
Diastoma alternatum[1]		x
Diastoma varium	x	x*
Eupleura caudata		x*
Haminoea succinea	x	x*
Marginella sp.		x
Melongena corona	x	x*
Mitrella lunata	x	x*
Mitrella sp.		x
Nassarius vibex		x*
Odostomia sp.	x	x
Stellatoma stellata		x*
Turbonilla protracta[1]		x
Turbonilla sp.	x	x
Urosalpinx cinerea		x*
Gastropoda unid.	x	x
Class Pelecypoda (Bivalvia)		
Amygdalum papyrium	x	x*
Anomalocardia auberiana	x	x*
Brachidontes exustus		x*
Geukensia demissa	x*	
Geukensia d. granosissima[1]	x	x
Laevicardium laevigatum		x*
Laevicardium mortoni		x*

TABLE 1. Continued.

SPECIES	LS	BR
Laevicardium sp.		x
Lyonsia hyalina floridana	x	x*
Macoma constricta	x*	
Macoma tenta	x	x*
Modiolus m. squamosus	x*	
Mulinia lateralis	x	x*
Ostreidae unid.	x	
Parastarte triquetra	x	x*
Rangia cuneata		x*
Tagelus divisus		x*
Tagelus plebeius		x*
Tagelus sp.		x
Tellina aequistriata[1]		x
Tellina mera[1]		x
Tellina paramera		x*
Tellina tampaensis	x	x*
Tellina versicolor		x*
Tellina sp.		x
Bivalvia unid.		x
Phylum ANNELIDA		
Class Oligochaeta		
Oligochaeta unid.	x	x
Class Polychaeta		
Acesta sp.		x
Amphicteis gunneri		x*
Arenicola cristata		x*
Aricidea fauveli[1]	x	x
Aricidea fragilis	x*	
Aricidea sp.	x	x
Asychis sp.	x	x
Axiothella mucosa		x*
Branchiasychis americana		x*
Brania clavata		x*
Brania sp.		x
Capitella capitata	x	x*
Chone americana		x
Clymenella mucosa		x*
Diopatra cuprea cuprea		x*
Diopatra sp.		x
Dorvillea sp.		x
Eteone heteropoda	x	x*
Eteone sp.		x
Exogone sp.		x
Glycera americana		x*
Glyceridae unid.		x
Glycinde solitaria	x	x*
Glycinde sp.		x
Goniada maculata[1]		x
Goniada sp.	x	
Goniadidae unid.	x	x
Gyptis vittata	x	x*
Haploscoloplos foliosus	x	x*
Hesionidae unid.	x	x
Hydroides sp.		x
Maldanidae unid.		x

TABLE 1. Continued.

SPECIES	LS	BR
Marphysa sanguinea	x	x*
Mediomastus californiensis	x	x*
Mediomastus sp.		x
Melinna maculata		x*
Melinna sp.		x
Mercierellopsis sp.	x	
Microphthalmus sp.	x	
Neanthes succinea	x	x*
Nereidae unid.	x	
Paraprionospio pinnata		x*
Pectinaria gouldii	x	x*
Phyllodocidae unid.		x
Podarke obscura	x	x*
Polydora ligni		x*
Polydora sp.		x
Polycirrus sp.		x
Potamilla reniformis[1]		x
Potamilla sp.		x
Prionospio heterobranchia		x*
Prionospio steenstrupi[1]		x
Pseudomalacoceras sp.		x
Sabellidae unid.		x
Serpula sp.		x
Spiochaetopterus costarum oculatus	x	x*
Spionidae unid.	x	
Spirorbis sp.		x
Streblospio benedicti	x	x*
Syllidae unid.		x
Tharyx setigera		x*
Tharyx sp.		x
Phylum SIPUNCULIDA		
Goldfingia pellucida		x
Phylum ARTHROPODA		
Class Crustacea		
Copepoda		
Harpacticoida unid.		x
Ostracoda		
Cylindroleberidae unid.	x	x
Podocopida unid.	x	x
Sarsiella disparilis	x	x*
Cirripedia		
Balanus sp.		x
Cumacea		
Cyclaspis sp.	x	x
Oxyurostylis smithi	x	x*
Tanaidacea		
Apseudis sp.	x	x*
[a]*Hargeria rapax*	x	
Leptochelia dubia	x	x
Tanaidacea unid.	x	x
Isopoda		
Cymodoce faxoni	x	x*
Edotea montosa	x	x*
Erichsonella filiformis	x	x*
Amphipoda		

TABLE 1. Continued.

SPECIES	LS	BR
[a]*Ampelisca abdita*	x	x*
[a]*Ampelisca vadorum*	x	x*
Corophium lacustre	x	x*
Cymadusa compta		x*
Gammarus mucronatus	x	x*
Gitanopsis tortugae	x	
Grandidierella bonnieroides	x	x*
Melita sp.	x	x
Mysidacea		
[aa]Mysidacea unid.	x	x
Decapoda		
Decapoda unid.	x	x
Rhithropanopeus harrisii	x*	
Xanthidae unid.	x	
Class Pycnogonida		
Pycnogonida unid.		x
Class Insecta		
Insecta unid.	x	x
Class Xiphosura		
Limulus polyphemus		x
Phylum ECHINODERMATA		
Apodida unid.	x	
Dendrochirotida unid.		x
Holothuroidea unid.	x	
Stelleroidea unid.		x

[a] Investigators had been listing these species as Tanaidacea unid. and *Ampelisca* sp. Identifications were made by Kalani D. Cairns of Harbor Branch Foundation, Ft. Pierce.
[aa] Probably *Bowmaiella dissimilis* and *Mysidiopsis bigelowi* (Harbor Branch).

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Academy Symposium

OBSERVATIONS ON THE DISTRIBUTION AND BIOLOGY OF EAST-CENTRAL FLORIDA POPULATIONS OF THE COMMON SNOOK, *CENTROPOMUS UNDECIMALIS* (BLOCH)

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Abstract: *Capture of 1167 juvenile and adult snook,* Centropomus undecimalis, *in marine, estuarine and freshwater habitats of east-central Florida from 1974 to 1980 made possible determination of spawning periods, migratory habits, growth rate, general feeding habits and principle habitat associations. Although some juvenile recruitment to the estuary took place throughout the year, recruitment peaked from June to August and October to January. Early juveniles, 15-20 mm SL were most abundant in freshwater and marsh habitats. After 4 to 6 mo, juvenile snook reached 100-150 mm SL and were no longer caught in freshwater tributaries and marsh habitats. Snook 150 to 300 mm SL (mean of 240 mm) long typically began to migrate into seagrass beds during March. Age of a 240 mm snook is estimated at 7 to 9 mo. Seagrass beds 5 to 15 km away from ocean inlets were preferred habitats for juvenile snook over 150 mm SL and significant correlation was apparent between the percentage seagrass cover and number of snook caught per unit effort. Snook remained in seagrass beds from 2 to 5 mo until they reached a length of 300 mm. Snook over 300 mm SL were found to occur in a variety of estuarine and marine habitats. Snook as small as 11 mm SL were piscivorous in freshwater feeding primarily on neonatal* Gambusia affinis, *secondarily on palaemonid shrimp and microcrustaceans. However, small marsh snook fed principally upon microcrustaceans until large enough to take fish and palaemonid shrimp. Seagrass bed snook preyed on abundant fishes (e.g.,* Anchoa mitchilli *and* Lagodon rhomboides) *and penaeid shrimp.*

The snook or robalo, *Centropomus undecimalis*, is an euryecious tropical species valued in fisheries throughout its range. *Centropomus undecimalis* occurs from Cape Hatteras to Rio de Janiero, Brazil, but is only common in the continental and insular Caribbean, southern Texas and lower Florida peninsula (Rivas 1962; Fraser 1968; Merriner et al., 1970).

Marshall (1958) and Volpe (1959) conducted the first extensive studies of the natural history of the snook. Their work precipitated from the statewide concern for reductions in commercial and sport fishery snook landings that took place during the 1950s. These studies concentrated on southwest Florida adult snook populations, giving estimations of fecundity, growth, age and feeding habits.

The natural history of southwest Florida juvenile snook populations was first treated by Fore and Schmidt (1973). One of the most important aspects of this study was the demonstration that early juvenile and post-larval snook are principally found in brackish to fresh upland marshes and streams. Fore and Schmidt also presented juvenile condition factors, growth rates, length-weight relationships and a feeding analysis.

Feeding habits of larval, juvenile and adult snook have also been examined by Marshall (1958), Volpe (1959), Harrington and Harrington (1961), Chavez (1963), Linton and Richards (1965), Austin and Austin (1971), Carvajal (1975) and Shafland (1977).

We sought to determine specific habitat associations of juvenile snook during various phases of ontogeny. Their growth rate, length-weight relationship, condition factors and general feeding habits were determined and compared with those of west-Florida specimens. Analyses of variations in environmental parameters such as rainfall, water temperatures, % seagrass cover, salinity and associated variations in snook populations were made. These analyses were intended to reveal critical parameters and habitats playing a vital role in the natural history of east-central Florida snook populations. Data presented are derived from 1167 specimens collected during several ichthyofaunal surveys made from 1974 to 1980. An additional 254 specimens were obtained from the ichthyological collections of the late Robert W. Harrington of the Florida Medical Entomology Laboratory at Vero Beach.

Methods—Monthly stations were maintained at 7 seagrass locations in the Indian River lagoon between Sebastian and St. Lucie inlets from March 1974 to August 1976 (Fig. 1). Two of these stations (WBC and JIS), were maintained until April 1977, and 1 (LPT), for 73 mo until December 1980. Monthly collections were made at various freshwater tributary sites in the Sebastian Creek drainage, (including Fellsmere Canal), South and North Relief canals (Indian River Co.) for 24 mo (1979-1980). Monthly collections were also made at the Blue Hole Point, Impoundment No. 23 marsh site (Bidlingmayer and McCoy, 1978) throughout 1980.

Snook were captured using 3.2 mm mesh beach seines of various lengths depending on the habitat collected. Seagrass seine hauls were made with a combination of a 67 x 1.8 m moving bag seine and a 15.3 x 1.8 m stationary barrier net following the methods of Gilmore, et al. (1978b). Salt marsh seine collections were made with a 15.3 x 1.8 m bag seine pulled over an 80 m transect. Freshwater seine hauls were made by placing a 3.1 x 1.8 m seine net parallel to shore and pulling it toward shore trapping the contained organisms against the bank. Overhanging vegetation was then disturbed displacing fish away from the bank and into the net which was then immediately raised. All techniques proved to be effective in capturing juvenile snook in several specific size classes.

Most specimens were fixed in 10% formalin immediately after capture. After fixation specimens were washed, measured (in standard length, SL, in 5.0 mm size classes) and weighed to the nearest 0.01 g. They were then preserved in 70% ethanol. Otoliths were removed from specific unpreserved specimens for age determinations following Volpe (1959). Only gonads, gut and otoliths were saved from specimens larger than 400 mm SL.

Standard length (SL) was measured from the tip of the snout to the posterior edge of the hypural plate. Standard length measurements were converted to fork lengths (FL) based on the conversion formula developed for snook by Fore and Schmidt (1973), FL = $-0.424 + 1.150$

SL. This allowed comparison of our length data relationships with those of previous workers whose fish were measured solely in fork length.

A coefficient of condition used by Fore and Schmidt (1973) for juvenile snook from the Florida west coast was also calculated:

$$K_{FL} = \frac{W\ (10^5)}{FL^3}$$

Where W = weight in gm and FL = fork length in mm.

Growth rates were predicted based on length frequency distributions and examination of otoliths from selected specimens. Early age classes were difficult to age accurately. The only comparable information for snook less than 60 da old were those of Shafland (1977) and Lau and Shafland (in press) for laboratory reared specimens and Fore and Schmidt (1973) for wild caught specimens. Considerable variation in snook growth rates was observed by Shafland (1977). We therefore conservatively placed a 13 mm standard length range of 10-23 mm for newly recruited snook and juveniles at an age of 30 da.

Water temperature, salinity and dissolved oxygen were monitored at all stations and were used in correlative analyses with snook. Salinity-length relationships were calculated using the

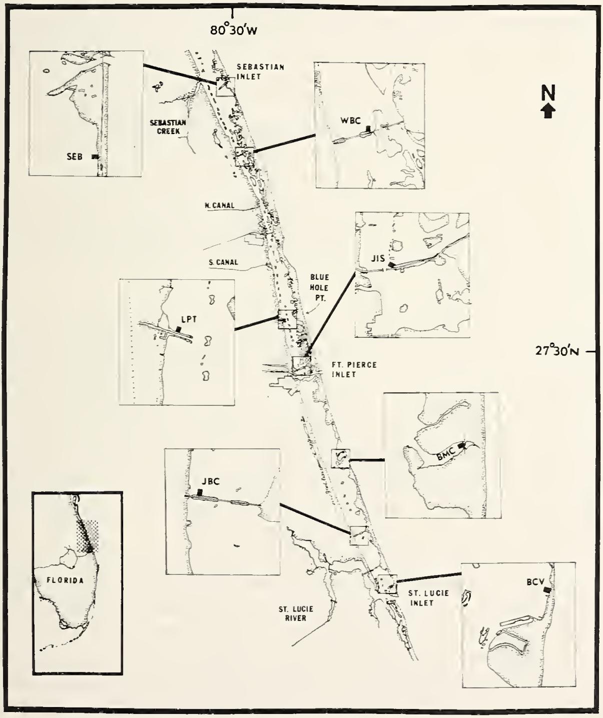

Fig. 1. Map of Indian River lagoon collection locations (i.e., SEB, WBC, LPT, JIS, BMC, JBC, BCV).

mean standard length for all fish collected at each salinity value. This eliminated much of the bias toward unequal collecting activity at various salinities.

We made generic identifications of specimens more than 7.6 mm long according to character states applied by Lau (1977) and Lau and Shafland (in press). *Centropomus undecimalis* larger than 10 mm were separated from *C. pectinatus* utilizing body depth to length ratios, relative orbit diameters, scale counts (once they had developed), relative anal spine lengths, and anal fin element counts. Separation of *C. parallelus* was not attempted, however, this species is rare in our area having only been recorded from the St. Lucie estuary and canal (i.e., locations in which we did not collect).

Stomach and intestinal contents were examined by counting individual prey organisms in generalized prey categories (e.g., microcrustaceans, fish, insects, etc.).

SPAWNING ACTIVITY RECRUITMENT AND GROWTH RATES — Weekly diurnal zooplankton samples (n = 725) taken within the Indian River lagoon from Ft. Pierce Inlet to Vero Beach (a transect of 22 km) from January 1976 to May 1978 produced only 2 snook larvae 7.6-9.0 mm SL at the ocean inlet station (James David, Harbor Branch Foundation, Inc., pers. comm.). The larvae are predicted to be 15 to 30 da old based on growth rates of Shafland (1977). Shafland (pers. comm.) predicts that his larval growth rates based on laboratory reared specimens are slower than those under natural environmental conditions. If this is true then our 7.6-9.0 mm specimens may be younger than 15-30 da. These observations suggest that snook spawning activity along the Florida east coast is not taking place within the Indian River lagoon nor within ocean inlets. Spawning activity in shallow nearshore waters is most likely, as large concentrations of gravid adults have been observed during summer and fall at various neritic locations between 27°30′ and 28°00′ N at depths less than 20 m (William Mitchell, Roy Hair, Richard Thomas, pers. comm.).

Our 2 ichthyoplankton specimens (7.6-9.0 mm SL) and the smallest seined specimens captured (11 mm SL) indicate larvae and early juveniles along the east-central Florida coast spend the first 15 to 30 da in transit from the spawning site to peripheral estuarine and freshwater nursery grounds. Current patterns on the inner continental shelf during the summer and fall are variable, but are generally characterized by a southerly long-shore drift with current velocities 30 to 50% less than those encountered at depths greater than 20 m (Kerr, 1980). Larval drift and movement north or south along the coast would eventually place them adjacent to an ocean inlet where they may ride tidal currents into the estuary.

Monthly length frequency data for 1167 snook captured between March 1974 and December 1980 show that spawning occurs throughout the year, though most activity occurs from May to November. Principal estuarine recruitment of post-larvae and juveniles occurred from June to August and October to January (Fig. 2). Oceanic salinities and the temperature moderating effects of the Florida Current produce stable salinities and water temperatures above 20°C on the east Florida continental shelf and in ocean inlets through much of the year (e.g., monthly means of less than 20°C occurred only during January and February during years studied, Gilmore

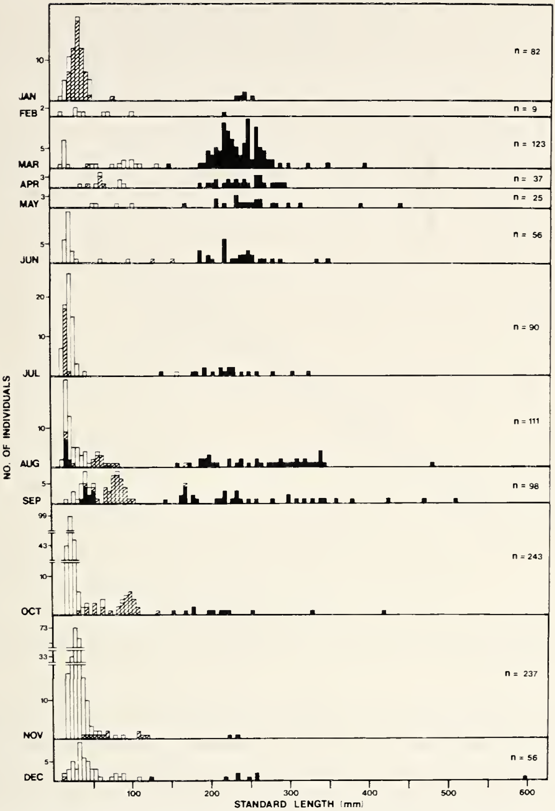

FIG. 2. Monthly length frequency distribution for 1167 *Centropomus undecimalis* for which length measurements were taken, 1974-1980. ■ = seagrass beds; ☐ = fresh water; ▨ = marsh.

1977, 1981). These conditions would be conducive to prolonged spawning activity for a tropical, stenothermic species such as the snook.

Our growth rates were calculated from length-frequency distributions with selective verification of the age of certain size classes using otoliths (Volpe, 1959). Length-frequency distributions based on monthly periods did not clearly delineate spawning times for some specimens. These specimens could be placed in either of 2 monthly spawning periods and were included in both for growth rate calculations (regression coefficients still remained high). Therefore, the number of snook presented in Fig. 3 surpass the

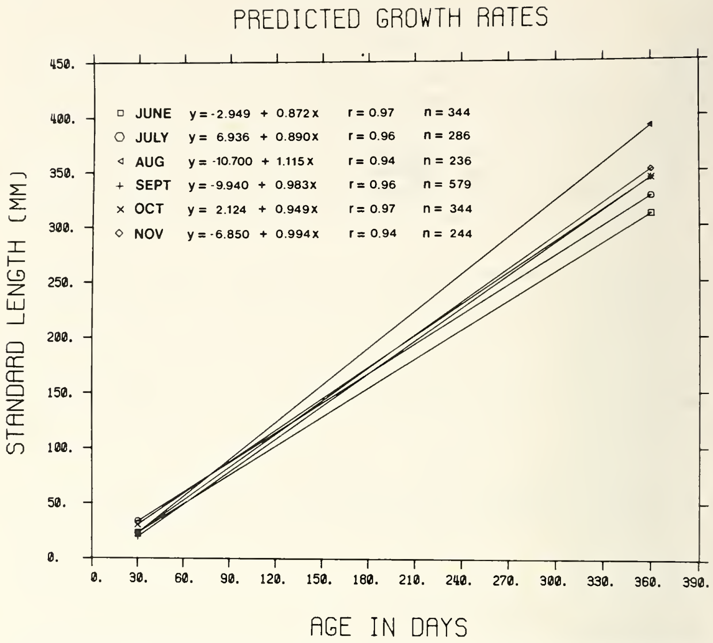

Fig. 3. Calculated growth rates of juvenile *Centropomus undecimalis* based on length frequency distributions.

number of snook collected and examined. Growth rates were determined for juvenile snook predicted to have spawned from June to November (Fig. 3). All of our calculated growth rates were similar (0.87-1.12 mm/da) and approximated the 1.00 mm/day growth rate given for juvenile snook (14-196 mm SL) by Fore and Schmidt (1973).

Spring-summer increases in recruitment coincide with seasonal increases in water temperature, however, this trend was not observed during fall and early winter. There was no significant statistical correlation between predicted monthly spawning activity (predicted from back-calculations based on growth rates) and mean monthly water temperatures. The lack of a correlation with temperature was partially the result of significant differences in recruitment of early juveniles (and therefore predicted spawning activity) during the warmer months and the recruitment of large numbers of juveniles during the fall and early winter when water temperatures are declining or low.

Salinities taken at the time of capture did not show a significant correlation with the number of juvenile snook captured. Salinity and general rainfall patterns also appeared to be independent of each other for the locations studied as there was no significant correlation between recorded salinities and rainfall at freshwater ($r^2 = 0.03$), salt marsh ($r^2 = 0.001$) and seagrass locations ($r^2 = 0.09$).

In contrast to overall temperature and salinity trends, precipitation levels revealed a positive relationship with snook recruitment. Predicted snook spawning activity based on growth rates and juvenile recruitment patterns during 1979-1980 showed a significant correlation with mean monthly rainfall ($r = .92$, 11 d.f. $P = 0.01$).

The effect of continental shelf physical climatic and hydrological parameters on the spawning activity of snook may also be exemplified with the passage of hurricane David on 3 September 1979. During the storm passage from 3 to 5 September, continental shelf water temperatures decreased 17.6°C, from 26.0 to 9.3°C at a depth of 26 m as cold slope waters encroached upon the shelf (Smith, 1982). A similar temperature drop also occurred at a depth of 10 m. It took 12 days for water temperatures to reach pre-hurricane levels of over 20°C. This temperature drop may have suppressed snook spawning activity by producing hypothermal stress, precluding movement into normal spawning grounds or increasing larval mortality. During 1979 and early 1980 predicted snook spawning activity was unseasonably great from November through January indicating that the passage of hurricane David may have delayed the maximum fall spawn for one or two months.

FRESHWATER COLLECTIONS — Six-hundred-and-ninety-two juvenile snook 11-156 mm SL, mean of 27.5 mm (predicted to be from 15 to 190 da old, mean age of 30 da) were collected from freshwater localities (Figs. 2, 4). Juvenile snook were most abundant in freshwater tributaries 1 to 2 mo following predicted peak spawning periods, i.e., July-August, October-November). There was a minor early spring recruitment peak in March due to larger individuals from the previous fall spawn occurring in the shallow peripheral bank microhabitat as water temperatures increased. There was a decline in numbers of fish less than 30 da old (<23 mm SL) during September. September fish <50 mm SL would have come from a predicted spawn occurring in July and August coincident with cold water upwellings on the continental shelf during July and August 1980 (Smith, 1981). October-December collections contained more specimens than did September collections (479 specimens). Most of the October-December fish were predicted to have spawned in September and October.

Nearly all freshwater snook were captured near stream banks and within or near bank vegetation (*Panicum purpurascens*, *P. repens*, and *Polygonum hydropiperoides*). After reaching 40-60 mm SL, 40 to 70 da old, juvenile snook begin to leave the bank habitat and either migrate to deeper water or out of freshwater streams into the salt marsh. Their residence in the peripheral freshwater tributaries (particularly along the banks) lasted from 10 to 40 da.

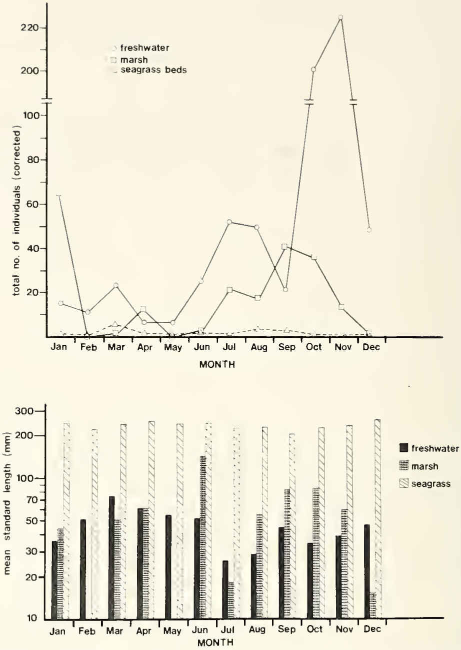

Fig. 4. Mean standard length (below) and numerical distribution of fish density (no./m²), which is a corrected value encompassing areal coverage per unit effort for all habitats collected (above).

The South and North Relief canals, 16.5 to 18.3 km away from the nearest ocean inlet, respectively, contained larger fish than Sebastian Creek adjacent to Sebastian Inlet and putative neritic spawning sites. Relief canal fish ranged from 11 to 133 mm SL (n = 128) with a mean length of 46.3 mm (predicted age of 45 to 60 days), while Sebastian Creek fish averaged 26.9 mm SL (n = 564), ranging from 13 to 86 mm. This suggests that relief canal fish reached the canals at mean lengths approximately 20 mm larger (20-25 da later) than did Sebastian Creek specimens.

Qualitative determination of the gut contents of 99 specimens (13-195 mm SL) collected in freshwater tributaries revealed that 44% of the snook contained fish, 21% shrimp, 15% microcrustaceans, 8% insects, while 30% were empty (Fig. 5). Approximately 67% of the fish remains in the gut were unidentifiable, while *Gambusia affinis* made up 25% of the total fish remains (76% of the identifiable fish). We found neonatal *Gambusia affinis* in the gut of juvenile snook as small as 11 mm SL). Shafland (1977: pg. 57 and 64) showed that 37 da old snook larvae (>9 mm SL) would aggressively con-

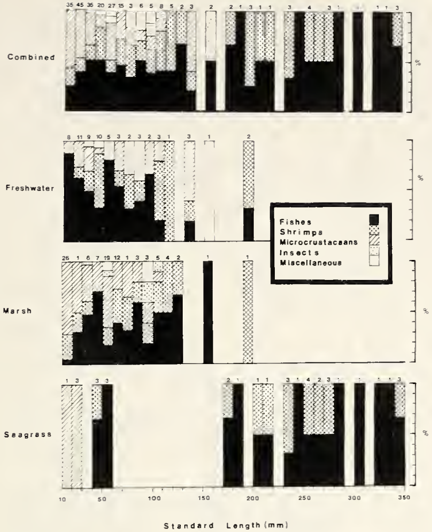

FIG. 5. Interhabitat comparison of the % contribution of all food items to the total food consumed by size. Number of snook examined per size class are given above bar.

sume "newly hatched" *Gambusia affinis* in captivity. The transition to a diet of small fishes (i.e., neonatal *Gambusia)* coincides with the observed arrival of snook in this size range at our marsh and freshwater sampling sites. *Gambusia* is the most abundant fish species at these sites (Harrington and Harrington, 1961; Gilmore et. al. in press).

SALT MARSH COLLECTIONS—From 1955 to 1968 salt marshes bordering the Indian River lagoon in east-central Florida were impounded for mosquito control. The 159 ha impoundment where we collected snook was recently reopened to the lagoon through a single culvert 80 cm in dia. Extensive vegetative regrowth had occurred and 41 species of fish were captured (Gilmore et al., in press).

One hundred and eighty-seven snook were captured in this habitat, 10 to 174 mm SL, (mean 67 mm) with an average predicted age of 70 to 80 da. Although we have collected snook as small as 10 mm (<30 da old) in the marsh habitat, most snook collected at our primary stations were 40-50 mm SL, (40 to 70 da old) and recruitment followed freshwater arrivals by several days to over a month later (Fig. 6). Most snook were captured in the salt marsh during September and October during maximal tidal flooding of the marsh. Marsh recruitment patterns follow freshwater patterns with a minor spring peak and a June-July rise followed by an August decline and a September-November maximum population (Fig. 4). The only significant

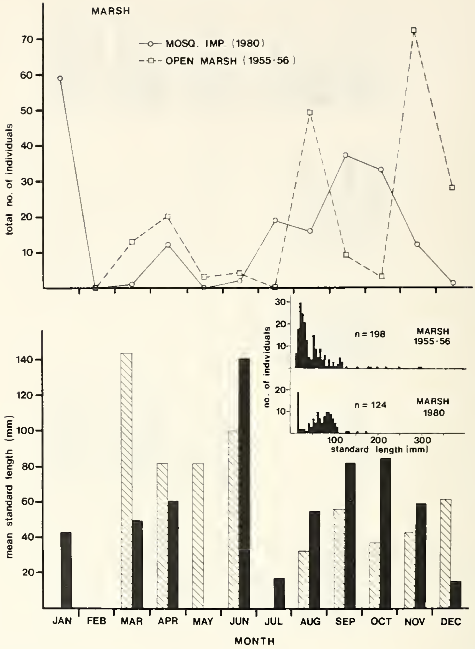

FIG. 6. Comparison between preimpounded open marsh juvenile snook collections (from Harrington collections 1955-56) and recent impounded marsh collections (1980). Inset shows the length frequency distribution comparison between historical open marsh collections and impounded marsh. ■ = mosquito impoundment (1980); ▨ = open marsh (1955-56).

difference was a very large January catch due to late fall spawning activity during 1979 following hurricane David.

After reaching lengths of 100 to 110 mm, 100 to 215 da after hatching, most snook leave shallow vegetated channels and ponds of the marsh after a residence period of 2 to 5 mo.

Only 26 snook between 100-150 mm SL have been captured from habitats studied (i.e., freshwater tributaries, salt marsh and seagrass beds). Because they are rare in habitats sampled they must occur in a transitional habitat(s) prior to migrating into seagrass beds. Deep channels within the Indian River lagoon and its freshwater tributaries may be the transitional habitat and offer migratory routes into and out of the various locations studied. Channel habitats were not sampled during the present study.

Salt marsh snook collections were also made in the study region by the late Robert Harrington (254 specimens, 1955-1956). Although his collections were principally exploratory and particular stations were not maintained through monthly collections, examination of his specimens and field notes has revealed complementary information on marsh snook populations during 1955 and 1956 prior to marsh impoundment. However, differences between his data and ours may reflect differences in the location and microhabitat sampled, sampling techniques, climatic and hydrological conditions, and not necessarily reflect differences in pre and post impoundment snook populations. A comparison between the mean size and seasonality of Harrington's snook and ours is made in Fig. 6. Snook collected by Harrington from August through November were smaller than our marsh specimens and therefore probably made a relatively short post-hatch migration directly to the marsh habitat. Our marsh snook (79% of them) had made a more prolonged migration to a marsh location whose access was limited to an 80 cm dia culvert. Our smaller specimens (<50 mm SL), within the size range of Harrington's specimens, occurred principally in freshwater samples. Harrington's seasonal data are difficult to interpret as he did not extend the same monthly sampling effort throughout the year.

Juvenile snook from the impounded salt marsh were found to have preyed principally upon microcrustaceans (35% of all fish examined) with fish (23%) and palaemonid shrimp (19%) forming numerically secondary food sources (Fig. 5). *Gambusia affinis* and *Cyprinodon variegatus* comprised the identifiable portions of the fishes consumed.

Examination of preimpoundment marsh collections made by Harrington reveals that microcrustaceans were also the principal food item in percent occurrence, while fish were secondary followed by palaemonid shrimp in barrier island marshes. Harrington also collected in mainland marshes and these specimens were found to differ from barrier island specimens in that they consumed palaemonid shrimp more often than fish. Of the identifiable fish consumed in Harrington's open marsh collections, 48% were *G. affinis*, 29% atherinids, the remainder, *Poecilia latipinna*, *Fundulus* sp., *Anchoa mitchilli* and *Lucania parva*. The barrier island marsh collections of Harrington and Harrington (1961) which are separate from the Harrington collections analyzed above are essentially in agreement with our data except that microcrustaceans formed a larger portion of the diet and fishes a smaller secondary portion.

Although Harrington's collecting effort (1955-1956) was not identical for barrier island (31 collections) and mainland (29 collections) marshes, a plot of his data reveal little difference between snook populations from the 2 locations (Fig. 7). Barrier island marshes are consistently more saline and have unstable salinity regimes (Gilmore, et al. in press). Mainland marshes generally receive upland freshwater flow in varying degrees and subsequently have lower and more stable salinities than barrier island marshes.

SEAGRASS BEDS—Seagrass seine collections produced 321 snook specimens, 15-600 mm SL (240 mm SL), between 1974 and 1980. These snook were collected at 7 stations between Sebastian and St. Lucie inlets from March 1974 to August 1976 (Fig. 1). Statistical analyses comparing

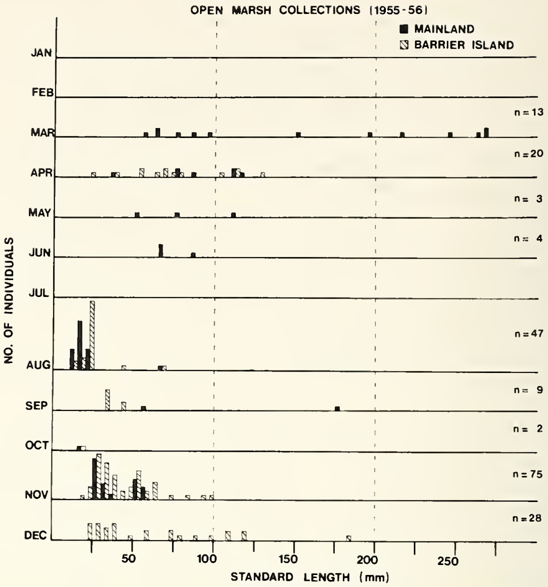

FIG. 7. Comparison between juvenile snook captured in barrier island marshes and mainland marshes.

percent seagrass cover were performed for only those dates when all 7 stations were sampled within a 27-36 hr period. Snook specimens were more abundant at stations located over 7 km from the nearest inlet (LPT to BMC, Fig. 8). Because juvenile snook abundance declined near inlet locations independent of seagrass cover; the JIS inlet station was omitted from the correlative percent seagrass cover analysis. These collections demonstrated an association between juvenile snook and seagrasses as there was a significant correlation (p = 0.01) between the percent total seagrass cover and the number of snook captured per unit effort (Fig. 9). No preference was observed for specific species of seagrass although 53% were captured at station LPT (1974-1976 only) which was dominated by *Syringodium* (76% total mean seagrass cover; 63.6% *Syringodium*; 11.7% *Halodule).*

Major recruitment of snook into seagrass beds occurred in March at a mean length of 240 mm (150-400 mm; Figs. 2, 10). Most of these snook were from the preceding spring-summer-fall spawn, had just completed their first winter and were 5 to 11 mo old based on our predicted growth rates and examination of otoliths (Figs. 2, 3 and 4). Snook between 200 and 300 mm SL occurred in seagrass beds throughout the year with minimum populations during periods of minimum seawater temperatures from November through

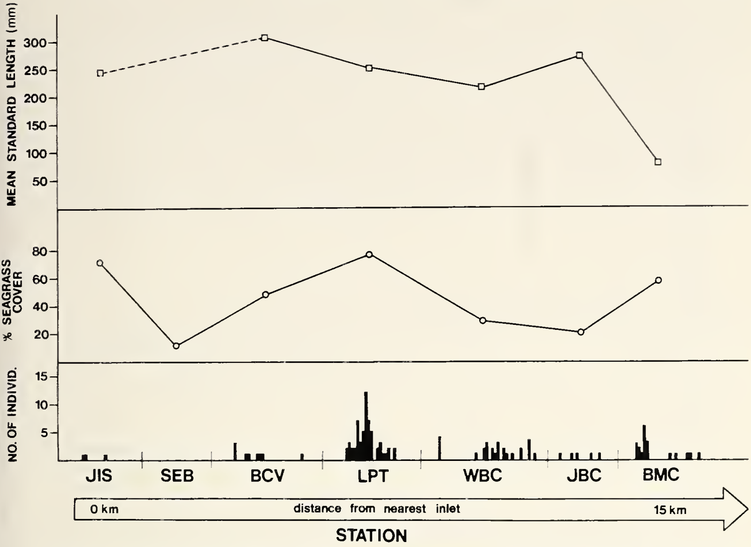

FIG. 8. Juvenile snook distribution at 7 seagrass stations monitored monthly from March 1974 to Aug. 1975, 1160 m^2 per collection.

February. After reaching 300 mm SL (age of 9 to 12 months) most snook migrated out of this habitat.

Eighty-two percent of the snook collected in this habitat were between 150 and 300 mm SL. Snook reside in seagrass beds from 1 to 6 mo before reaching 300 mm SL. At 300 mm SL, snook begin to mature and are entering their second year (Marshall, 1958; Volpe, 1959; Fore and Schmidt, 1973). Most are mature by 415 mm SL.

Snook captured in seagrass beds preyed principally upon fish, which were found in 58% of the snook examined. Approximately 24% contained penaeid shrimp (Fig. 5). Microcrustaceans were only consumed by small individuals (<50 mm SL) collected at WBC and BMC. These latter individuals were collected in seagrass beds adjacent to mangrove marsh habitat. Overall, *Anchoa mitchilli* was found in 28% of the stomachs, *Lagodon rhomboides* in 8%. Other species made up 6%, while 28% of the fish remains were unidentifiable.

There was a consistent occurrence of juvenile snook in seagrass beds through several tidal cycles and moon phases. There is no significant correlation with any particular tide or moon phase (Table 1). This demonstrates that the occurrence of juvenile snook in seagrass beds is independent of these two variables which change daily and weekly.

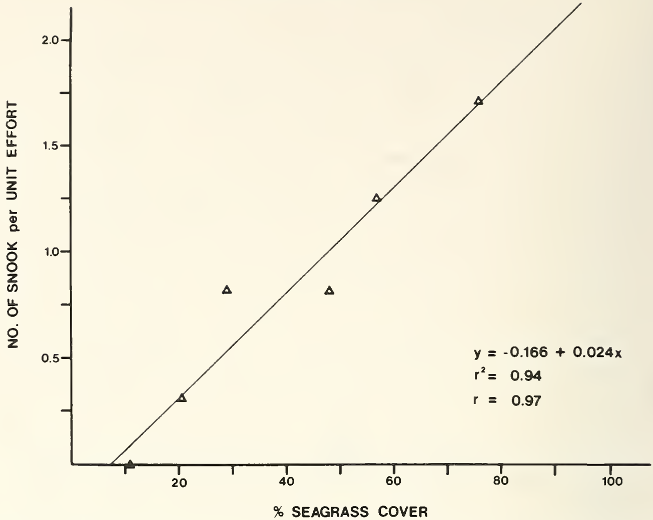

Fig. 9. Number of snook per unit effort between stations and correlation with % seagrass cover.

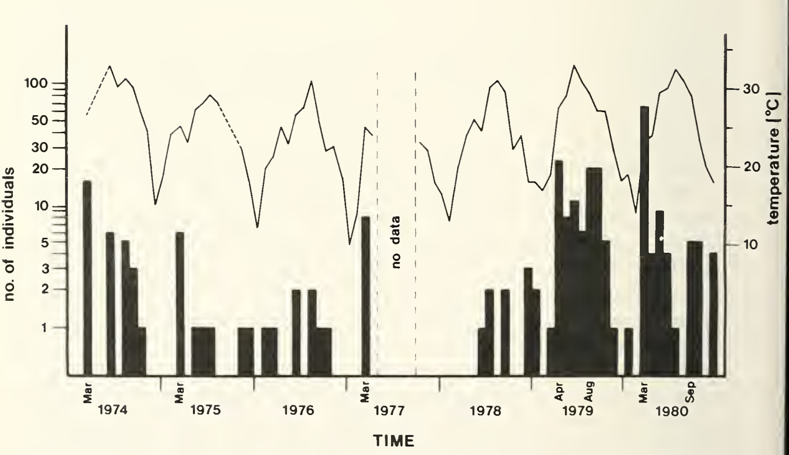

Fig. 10. Seven year seagrass snook recruitment pattern and water temperature patterns.

CONDITION COEFFICIENTS AND LENGTH-WEIGHT RELATIONSHIPS — Fore and Schmidt (1973) calculated a coefficient of condition (K) for juvenile snook captured in Ten Thousand Island tidal stream habitats (salinities of 0.4-29.7 ppt). Their values ranged from 0.77 to 1.52 with a mean value of 1.05 (n not given). Juvenile snook from tidal streams and freshwater tributaries of the Indian River lagoon had K values ranging from 0.24-1.36 with a mean of 0.93 (n = 194). Marsh and seagrass specimens had similar K values (Table 2) even though K values had a tendency to be lower for smaller individuals characteristic of freshwater habitats.

TABLE 1. Snook occurrence in seagrass beds with moon and tidal cycles. $X^2 = 2.00$, $X^2_{0.5[3]} = 2.366$ for equal occurrence at any moon phase and $X^2 = 3.15$, $X^2_{0.1[3]} = 6.251$ for equal occurrence at any tidal phase.

Moon Phase	New	1st Quarter	Full	Last Quarter
No. Observations	34	59	34	28
No. Occurrences of Snook	7	13	11	9
% Snook Occurrence	21	22	32	32

Tide Phase	Flood	Slack High	Ebbing	Slack Low
No. Observations	30	35	34	39
No. Occurrences of Snook	6	13	10	13
% Snook Occurrence	20	37	29	33

TABLE 2. Snook condition coefficient (K) variations by size and habitat. $\bar{K}$ = mean condition factor for the sampled group; K range = range of K coefficients; N = number of samples; SD = standard deviation; SE = standard error.

Standard Length (mm)	$\bar{K}$	K Range	n	SD	SE
10-50	.94	.24-1.56	231	.22	.01
51-100	.89	.65-1.14	95	.10	.01
101-150	.91	.66- .99	24	.11	.02
151-200	.94	.72-1.36	25	.25	.05
201-250	.97	.52-1.82	108	.14	.01
251-300	.95	.65-1.27	53	.12	.02
300	.98	.58-1.73	31	.23	.04

Habitat	$\bar{K}$	K Range	n	SD	SE
Freshwater	.93	.24-1.36	194	.21	.01
Marsh	.89	.62-1.37	132	.12	.01
Seagrass	.96	.52-1.82	235	.18	.01

One major difference between our collections and those of Fore and Schmidt may allow for lower K values and leaner juvenile snook on the east-central Florida coast. We included fish captured from January through May in our collections, while Fore and Schmidt only collected snook from June through December. Minimum K values were consistently observed during January and February in our collections and therefore reduce the overall average values. However, mean K values for fish from freshwater tributaries and comparable periods of the year (June-December) were only slightly lower for the Florida east coast populations (i.e., 0.24-1.36, K = 0.99, n = 173).

Our length-weight regression analysis using 553 fish from all habitats studied (Fig. 11) was also comparable to the length-weight relationship for juvenile snook determined by Fore and Schmidt (1973).

INTER-HABITAT VARIATION IN PHYSICAL PARAMETERS—Water temperature, salinity and dissolved oxygen were monitored in each of the 3

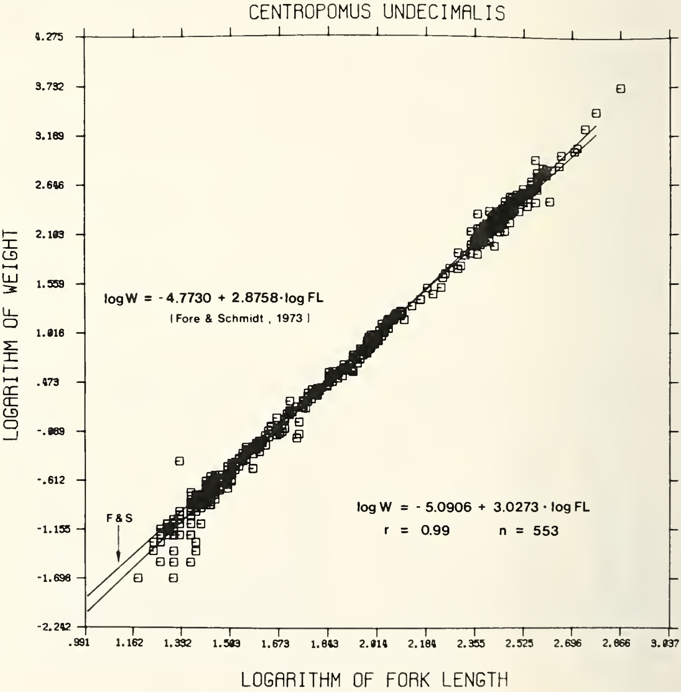

FIG. 11. Length-weight relationship of juvenile snook collected from the Florida west coast (Fore and Schmidt, 1973) and the Florida east coast. All points plotted are for east coast snook.

Table 3. Habitat variation in water temperature, salinity (SAL) and dissolved oxygen (DO), from data collected 1974-1980. Seagrass dissolved oxygen data were furnished by John Montgomery, Harbor Branch Foundation, Inc.

	Freshwater Tributary	Salt Marsh	Seagrass
TEMP (°C)			
n	192	36	222
Range	16-32	13.5-30	10-33
$\bar{x}$	24.8	24.5	23.9
S_x	4.3	4.8	5.5
$S_{\bar{x}}$	0.39	0.99	0.71
SAL (‰)			
n	192	36	222
Range	0-13	25-38	17-40
$\bar{x}$	2.4	32.2	30.3
S_x	3.2	4.3	5.3
$S_{\bar{x}}$	0.30	0.87	0.69
Dissolved Oxygen (ppm)			
n	192	36	98
Range	3.5-10.4	2.2-7.5	0.2-10.8
$\bar{x}$	6.95	4.47	5.30
S_x	1.57	1.58	2.63
$S_{\bar{x}}$	0.20	0.32	0.31

habitats in which snook were collected (Table 3). All 3 habitats had similar mean water temperatures, however, the range and variation was lower in freshwater tributaries. The lowest water temperature was 16°C at freshwater locations while a minimum of 10°C was reached in the seagrass habitat. During February, when water temperatures were usually at a minimum, snook occurred consistently only in freshwater tributary collections.

Juvenile snook populations are apparently not readily affected by major salinity changes; however, there is a significant correlation ($r = 0.62$; $df = 35$, $P = .01$) between the size of juvenile snook and the salinity of the habitat (Fig. 12). Larger juvenile snook (>150 mm SL) occurred consistently at higher salinities while smaller snook (<50 mm SL) were more variable but generally occurred in lower salinity habitats.

Dissolved oxygen values showed greatest variation in seagrass habitats although lowest values were recorded in marsh habitats. Oxygen levels are most likely limiting factors in confined or isolated marsh locations. Snook movement into the salt marsh occurs during maximum seasonal flooding of the marsh with coincident increases in dissolved oxygen levels.

Discussion—Our data demonstrate that juvenile snook utilize at least 3 distinct coastal habitats during the first 12 mo after hatching: freshwater tributaries, the salt marsh and seagrass beds. The rare occurrence of larvae and 100-150 mm juvenile snook in hundreds of collections taken over extended periods of time indicate that 2 additional habitats are inhabited only in a transitional or migratory mode during early development: (1) larvae in

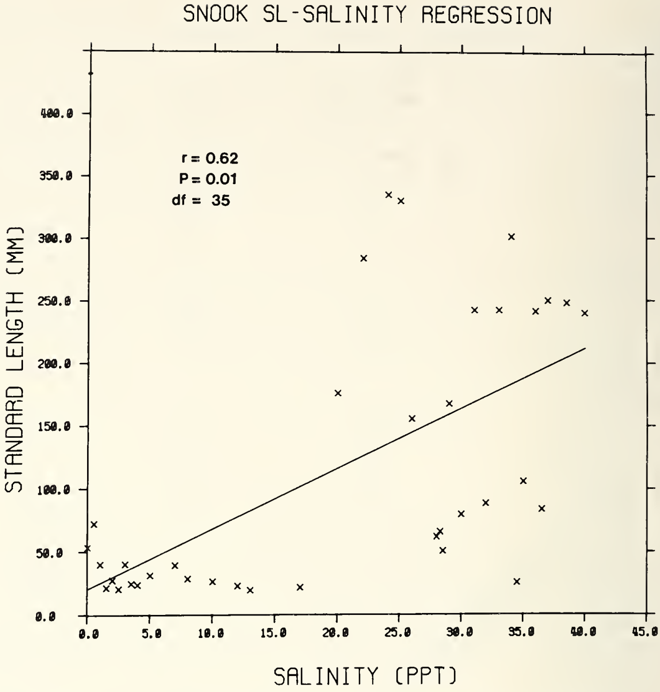

Fig. 12. Relationship between mean fish length (SL) and salinity at time of capture.

the neritic habitat would undergo a denatant migration from the spawning site to the ocean inlet (with predicted period of 15-30 da) and (2) 100-150 mm juvenile snook apparently inhabit estuarine channels connecting the freshwater tributaries and marshes to the open estuary during the 2-3 mo transit from freshwater and marsh habitats to seagrass beds.

A recapitulation of juvenile snook movements during their first year can now be made (Fig. 13). Snook averaging 27.5 mm SL (11-156 mm, 15-190 da old, mean of 30 da) are found in freshwater tributaries. They reside at these locations for approximately 10 to 70 da, arriving at lengths of approximately 11 mm and most leaving at 40-60 mm. Some may leave after reaching 100 mm. Juvenile snook in the marsh habitat average 67 mm SL, (10-174 mm, 15-220 da mean of 75 da), indicating that snook spend an average of 45-55 da in transit to the impounded marsh after entering the ocean inlet. Marsh residency lasts 60 to 90 da. Marsh recruitment patterns generally follow that of freshwater tributaries with a summer and fall peak in numbers. Snook reaching 100 mm migrate from the marsh to some transitory habitat before

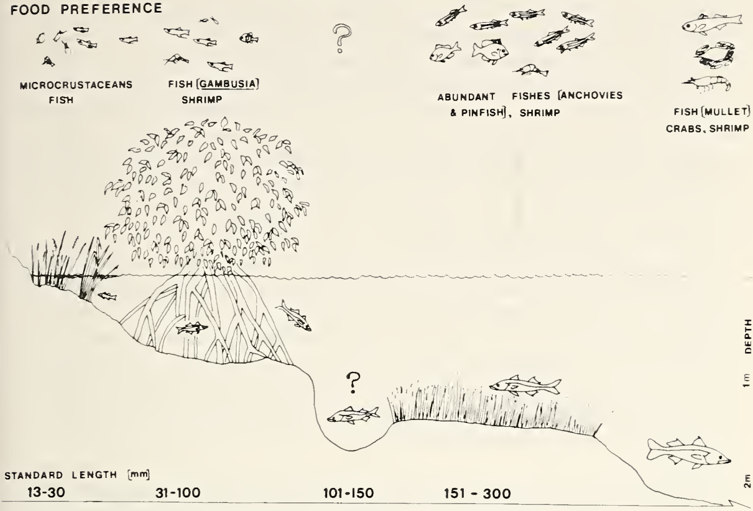

FIG. 13. Schematic representation of juvenile snook migration and association with various habitats and subsequent changes in food items consumed.

entering seagrass beds at lengths over 100-150 mm SL (age over 4 mo). Seagrass snook average 240 mm, 220-285 da in age and reside in this habitat for approximately 4 mo. Approaching a length of 300 mm maturation begins and snook migrate from the seagrass habitat.

While residing in freshwater tributaries juvenile snook prey principally upon fish (neonatal *Gambusia affinis)*, secondarily on palaemonid shrimp and microcrustaceans (Figs. 5 and 13). Marsh snook prey principally upon microcrustaceans, fish (neonatal *Gambusia affinis* and *Cyprinodon variegatus)* and palaemonid shrimp. Smaller individuals preyed predominantly on microcrustaceans while larger snook (100 mm SL) preyed on fish and palaemonid shrimp. In the seagrass habitat snook preyed principally on fish (abundant species, i.e., *Anchoa mitchilli* and *Lagodon rhomboides)* and penaeid shrimp.

Our observations of the feeding habits of juvenile snook from the Indian River lagoon and its tributaries do not differ greatly from those of others (e.g., Fore and Schmidt, 1973; Shafland 1977). We have analyzed our data by habitat to reveal the various basic qualitative differences between habitats and ontogenetic changes. We have also shown that very young snook (11 mm SL) may consume fish. Shafland (1977) had successfully fed neonatal *Gambusia affinis* to juvenile snook (>9 mm SL) reared in the laboratory. We verified these observations in the field by finding neonatal *Gambusia* in an 11 mm SL snook captured in a freshwater tributary. We found *Gambusia affinis* to be a common prey item in general for early juvenile snook occurring in freshwater tributaries.

This is the first determination that seagrass beds act as a principal habitat for juvenile snook during a specific phase in ontogeny. Our observations in various seagrass beds reveal that only specific beds are utilized and that percent seagrass cover and distance from ocean inlets play a significant role in governing dispersal. Seagrass beds on the Florida west coast may have been sampled inadequately or if sampled, were not at the optimum location to be utilized by snook. Thus, it is uncertain whether or not this phenomenon is unique to the Indian River lagoon.

Our observations of predicted spawning activity based on juvenile recruitment patterns indicate a prolonged spawning period with several peaks in activity. Although spawning activity may occur from April to December, our 1979-1980 freshwater and marsh impoundment collections indicate that the later summer-fall spawning period was the most significant spawning period during the year. Our grassbed data indicate that the June-July spawn for 1978-79 was relatively large, although these were older fish whose numbers were less representative of relative numbers of eggs and larvae.

Although east coast spawning activity is similar in many respects to west coast observations (Marshall, 1958; Fore and Schmidt, 1973) it differs in that spawning activity begins earlier in the spring and may continue into December. West coast studies have shown that the first spawn occurs in May and June and can continue into November with major activity during early summer. In addition to having a major spawn in June and July, east coast snook have a major spawning peak from August to October. This is a minor spawning period on the Florida Gulf coast. These differences between coastal populations may be associated with differing physical parameters promoting spawning activity and larval-juvenile survival. Differences in spawning activity are not unlikely, considering the quite different hydrological and water temperature regimes between the east and west coastal zones of Florida and the general non-migratory nature of snook (Moe, 1972). Thermal conditions during winter months are quite different between Gulf coastal Florida and the Atlantic coast at the same latitude (Gilmore et al., 1978a; Gilmore and Hastings, in press). Shallow coastal waters of the Gulf of Mexico reach lower temperatures for longer periods of time. Therefore, it is likely that spawning times for a tropical species found on both coasts of the Florida peninsula would differ.

Spawning activity (mean number of snook predicted from juvenile recruitment patterns to have been spawned per month) on the Florida east coast was found to be correlated significantly with monthly rainfall patterns although not with salinity and temperature. In the region studied there was a more distinct seasonal change in rainfall through much of the year than in water temperature and salinity (Wilcox and Gilmore, 1976; Gilmore et al., 1981), particularly on the continental shelf (Ned Smith, pers. comm.). Rainfall and subsequent terrestrial rainwater runoff directly affect dissolved nutrient levels and plankton production. The quality and quantity of plankton consumed by snook larvae during early development would have to occur in adequate concentrations to support the drifting larvae and would affect larval mortality.

The only observations of larval snook growth were made under captive conditions by Shafland (1977) and demonstrate that larval and early juvenile snook (<30 mm SL) probably grow at a slower rate than larger juveniles (i.e., <30 mm SL). Shafland observed a standard length range of 5.3 to 14.3 mm at 27 da. He raised snook up to 92 da and length of 90 mm. Snook <20 mm were observed to grow much slower (0.32 mm/da) than those between 20 and 90 mm SL (1.57 mm/da, 30 da old). Shafland (pers. comm.) emphasizes that it was difficult to maintain larval snook in captivity and therefore the growth rates he observed were not considered representative of typical larval snook growth rates, but were most likely underestimates at lengths below 20 mm, particularly for fish <30 mm SL.

The only extensive collections of juvenile snook for which growth rates were determined are those of Fore and Schmidt (1973). Their mean value of 1.00 mm/da compares favorably with our values of 0.87-1.12 mm/da and those of larger juvenile snook raised by Shafland (1977; 0.98 mm/da). These observations demonstrate that snook between 30 mm and 300 mm show the highest growth rate.

The only juvenile growth rates in the literature that differ significantly from our values are those of Volpe (1959). Volpe collected principally adult fish. Only 18 of the 590 snook he measured were less than 360 mm and could possibly be considered juveniles. His calculated size and age for juvenile snook are therefore the least accurate of his predicted age groups. In addition, Volpe states . . . "Due to net selectivity and sampling problems, it was not possible to construct an accurate growth curve from the observed data, so this curve was drawn from the calculated data." Volpe's growth data are most accurate for year II fish and older. Volpe examined a 225 FL (196 mm SL) snook captured on 5 December which was entering its first winter (Volpe 1959; pp. 42, Fig. 9). This fish was from the previous summer's spawn (May-September). The oldest age it could be, based on observed spawning times in Volpe's study, would approximate 180 da giving a mean growth rate of 1.10 mm/da. However, in contrast, Volpe calculated the mean length of snook to be 163 mm TL (135 mm SL) after the first winter which would agree with our data only if they were late summer or fall spawned snook not early summer specimens. Volpe calculates a mean growth rate of 0.49 mm/da between the 1st and 2nd winters. We feel that extrapolation of growth rates from adult fish in their second year to juveniles in their first year leads to an underestimate of the juvenile growth capacity at lengths between 20 and 300 mm SL which we and others (Fore and Schmidt, 1973) determined to be between 0.87 and 1.12 mm/da. However, Volpe does state that . . . "rate of growth is high to the second year, then is fairly uniform to the fifth year, and slowly declines thereafter." From the present data in the literature and from our observations, the growth rate of snook appears to follow a classical pattern of slow initial growth just after hatching (i.e., ca. 0.32 mm/da or less) for the first month, followed by a nearly tripled rate of ca. 1.00 mm/da, which after the first year slows to an adult rate of ca. 0.50 mm/da or less (the latter rate was observed by Volpe, 1959).

Our data also show east-central Florida juvenile snook populations have weight per unit length and K values that are comparable to those observed for the Florida west coast. As Fore and Schmidt (1973) present the only data for comparing juvenile populations from the Florida west coast, differing methodologies and collecting periods may have affected K value comparisons. Ambient temperature regimes, qualitative and quantitative state of food organisms and varying degrees of environmental stress, etc. may all affect fish weight and may account for any differences observed between our study and the historical collections of Fore and Schmidt (1977).

We observed that as east coast snook grow, they progress through various habitats with a correlative increase in ambient salinities. Although Fore and Schmidt (1973) were not able to find a correlative relationship between salinity and standard length, we found a significant relationship in east coast juvenile populations (Fig. 12). Our observations show that there is a movement from lower salinities to higher salinities and seagrass beds as ontogeny progresses. This may not have always been the case as historical marsh collections made prior to impoundment indicate that smaller snook occurred in more saline marsh habitats. During the 1950s and 1960s, 48%, or 410 km of the lagoon shoreline, surrounding 14,580 ha of coastal marsh in the Indian River lagoon system, were impounded (Jack Salmela, pers. comm.; Bidlingmayer and McCoy, 1978). Therefore most of the marsh habitat was inaccessible to juvenile snook when our collections were made. This vast removal of juvenile habitat would have a direct impact on juvenile mortality rates and subsequently the adult populations.

Snook were also confined to the downstream side of flood gates, salinity barriers and spillways in freshwater tributaries. These structures limit the available freshwater habitat to that distance between the Indian River lagoon and the barrier. Limited portions of these streams were treated with herbicides virtually eliminating shoreline vegetative cover utilized by juvenile snook. Freshwater quality was also variable with secondary and primary sewage effluent, farm stock effluent, agricultural pesticide and herbicide runoff, urban runoff, and direct herbicide application impacting various collecting sites. The effect of various degrees of freshwater quality on juvenile snook has not been determined. We reiterate the opinion of Marshall (1958) in that loss of habitat and general degradation of water quality has undoubtedly had a more permanent and therefore greater effect on reducing snook populations than the fishery. Removal of juvenile habitat curtails recruitment from the largest portion of the snook population and that portion which is most susceptible to natural mortality.

After maturation at 400-500 mm SL, *C. undecimalis* is somewhat alleviated of much of the habitat specificity and predation pressure that was exerted on juvenile populations as it is now one of the larger estuarine predators (maximum size near 1397 mm TL 22.9 kg, McClane, 1973). Since under natural conditions nearly all estuarine shorelines of south Florida (south of 28°00′ N. latitude) were lined with mangrove stands, it is natural to assume the mangrove biotope to be the principal habitat of adult snook as was done in early life history studies of adult snook (e.g., Marshall, 1958). However, there has been an extensive reduction of mangrove marsh and shoreline, particularly along the southeast coast of Florida, yet it is still possible to capture adult snook in a variety of habitats including nearshore reefs, seagrass flats, sandy beaches, deep channels, inlets, jetties, and along bulkheads and other denuded shorelines in fresh, brackish or marine waters. It is apparent from this distribution pattern that adult habitat requirements are not as narrow as those of juvenile snook. However, during larval and juvenile development, when predation on the snook population is at its peak and metabolic requirements are high, the habitat is of prime importance and subsequently east-central Florida snook populations under 300 mm SL are confined to peripheral areas in freshwater tributaries, salt marshes and seagrass beds.

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MARINE TURTLES
OF THE INDIAN RIVER LAGOON SYSTEM

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Abstract: *Documents describing the Indian River marine turtle fishery, which flourished in the late 1800s, are the only source of information concerning lagoonal turtle populations prior to 1978. The primary object of the fishery, which declined after 1900, was the green turtle,* Chelonia mydas. *The other important species in the system, the loggerhead turtle* (Caretta caretta) *is mentioned briefly in the early reports. Studies of these 2 species in the northern segment of the Indian River lagoon system were carried out from July 1976 to September 1981. Turtles were captured in large-mesh tangle nets and during hypothermic stunning episodes in the winters of 1977 and 1981. The presence of* Eretmochelys imbricata *and* Lepidochelys kempi *in the system is recorded for the first time. A total of 205* C. caretta *and 199* C. mydas *was captured, providing a basis for the characterization of the 2 populations. Loggerhead turtles of the system are about twice as large (weight $\bar{x}$: 43.7 kg; CLSL $\bar{x}$: 65.8 cm) as green turtles (weight $\bar{x}$: 18.8 kg; CLSL $\bar{x}$: 48.2 cm), but virtually all green turtles and 95% or more of the loggerheads are immature. Indian River lagoons are "developmental habitats," in the sense of Carr et al. (1978).*

Landings statistics and notes associated with them in reports to the U.S. Commissioner of Fish and Fisheries in the late 1800s constitute the only sources of information concerning marine turtles of the Indian River lagoon system prior to 1978. Partly because of the emphasis on turtles as a commodity, many subsequent changes in geographic designations and the primitive state of marine turtle taxonomy before the turn of the century, those reports generally provide more questions than answers about the marine turtle populations of the system.

The Indian River turtle "fishery" was begun prior to the Civil War, but in those days the catch was mostly bartered to merchant and government vessels (True, 1887). It was apparently not until the 1870s that arrangements with northern markets were established through agents in Jacksonville.

True (1887) and Wilcox (1896) reported that the turtle fishery was only pursued in the winter months (November - March) because of the danger to the nets presented by large sharks and sawfish. Brice (1896) and Wilcox (1896) described the nets used as being constructed on the principle of ordinary gill nets; composed of coarse thread, with a 71 cm stretch mesh, 85-115 m long and 10 meshes deep. Ordinarily, 2 fishermen worked 4 to 6 such nets at one time.

It is clear that the green turtle, *Chelonia mydas*, was the primary object of the fishery. Loggerhead turtles, *Caretta caretta*, were not sought after but, judging by present day standards (Mendonca and Ehrhart, 1982), must have been at least as common as green turtles. Only a few pounds of loggerhead meat entered the market and the reports do not say how many were captured along with the highly-sought-after green turtles. It is often difficult to remove a loggerhead from a net and it is very possible that this species was regarded as undesirable by-catch, like sharks, sting-rays and sawfish. It may be that many were destroyed to prevent repeated entanglement in the nets. The low esteem in which loggerhead flesh was held is told in the following passage from True (1884): "The flesh of the adult is leathery and oily, and smells very strongly of musk; it is therefore, not generally eaten although some pretend that they have partaken of its flesh without nausea."

The reports suggest that the Indian River turtle fishery was at least partly responsible for the rapid decline of these populations through over-exploitation after trade in the animals and their products became commercialized (Brice, 1896; Wilcox, 1896). The commercial fishery did not begin until 1878, when a Connecticut vessel visited one of the inlets to catch fish for the Savannah market (Brice, 1896). It was in that same year, however, that the fishery was most successful, with 8 fishermen capturing 1,600 green turtles (True, 1887). The following winter (1879-80), 1,400 turtles were captured by 16 fishermen and 9 yr later (1886), Mr. Charles Pearke of Sebastian, took 2,500 turtles with 8 nets (Wilcox, 1896). That was apparently the peak because just 9 yr later (1895), Mr. Pearke was able to capture only 60 turtles, and he reported that by that time turtle fishing on the Indian River was much less productive than formerly (Wilcox, 1896).

It was in that same year that the so-called "Great Freeze of 1894-95" occurred. Wilcox (1896) reported that hundreds of turtles were found floating at the surface in a stunned condition, and that most were picked up, warmed and promptly sent on their way to northern markets. He noted that, "since the cold spell turtles have been much scarcer than ever." That was apparently the beginning of the end for the Indian River marine turtle fishery and, although some netting continued into the 1960s, it was not an important enterprise after about 1900.

In the conclusion of his report, Brice (1896) noted that the green turtle needed protection to prevent its extirpation. He called for a moratorium on the taking of nesting adult females, a minimum weight limit on turtles sold and an end to what he called "the pernicious and destructive practice of gathering the eggs of this and the loggerhead turtle." It was not until 60 yr later that the first legislation protecting marine turtles was passed in Florida and not until 1971 that they became fully protected. In 1978, more than 80 yr after Brice's admonition, green turtles and loggerheads were designated endangered and threatened species, under terms of the Endangered Species Act of 1973, and became fully protected by the federal government.

It was probably as a result of the decline of the turtle fishery around the turn of the century that the biology of Indian River marine turtle populations was neglected for the next 75 yr. In 1975, after pilot studies had shown that *Chelonia* and *Caretta* were still present (Ehrhart and Yoder, 1978), my students and I began an extensive study of these animals in Mosquito Lagoon and in the northern reaches of Indian River and Banana River. Partial results of that study, dealing with the 2 most common species (*C. mydas* and

C. caretta) in Mosquito Lagoon only are given in Mendonca and Ehrhart (1982) and constitute the beginning of the characterization of these populations. Further results, dealing with these 2 species and 2 additional ones, from all 3 of the estuaries, will be given here, so as to further the morphometric definition of the marine turtle community in the Indian River lagoon system. Mendonca (1981) has recently contributed much useful information about the movements and food habits of green turtles in Mosquito Lagoon.

Study Area and Methods—From July 1976 to September 1981 nets that are essentially identical to those formerly used by turtle fishermen and ranging in length from 150 m to 230 m were set in the lagoons for a total of 6650 hr (277 da). Turtles that became entangled were never harmed by capture of this kind. The general location of the study area is shown in Fig. 1. The dots on the map designate the actual netting sites; the size of the dots is proportionate to the level of effort (netting time) expended at those sites.

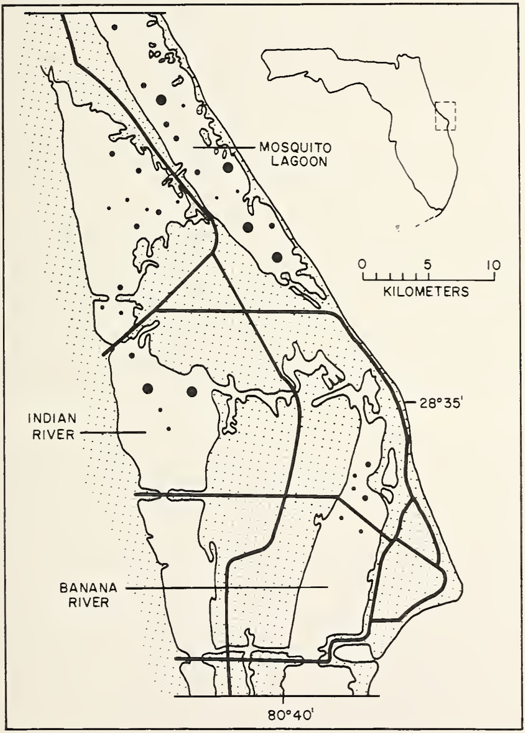

Fig. 1. Deployment sites (designated by dots) of marine turtle capture nets in Mosquito Lagoon, Indian River and Banana River, 1976-1981. The size of the dots is proportionate to the level of effort (net deployment hours) expended at the sites.

A phenomenon that may be unique to the northern part of the Indian River lagoon system provided much additional information for the characterization of these populations. The stunning and complete immobilization of marine turtles by low water temperatures (like that reported in 1894-95) occurred on a large scale in the winters of 1977 and 1981. Over 300 marine turtles were brought to the laboratory of the Merritt Island National Wildlife Refuge during those episodes.

The following shell measurements were made of each turtle, whether net-captured or cold-stunned: straight-line carapace length (CLSL), carapace length over curvature (CLOC), carapace width, straight line (CWSL) and over curve (CWOC), and plastron length (PL). Maximum head width (HW) and weight (WT) were also measured. Where injuries had altered the normal shape of the shell, the data were omitted from the calculation of means and other summary statistics.

RESULTS AND DISCUSSION—*Lepidochelys kempi* (Kemp's ridley) is basically a Gulf of Mexico turtle. Adult females nest only at Rancho Nuevo, on the coast of Tamaulipas, Mexico. A few Kemp's ridleys make their way around the Florida peninsula and proceed northward along the Atlantic coast to the New England states. Brongersma (1972) has compiled these records for each of the Atlantic coastal states and there are a number of records from the Florida east coast. The species was, however, not previously known to enter the coastal lagoons. Three *L. kempi*, 1 from the Banana River and 2 from Mosquito Lagoon, were captured, examined and tagged during this study. Morphometric characteristics of these 3 specimens are in Table 1. Cranial measurements are available for the largest of the 3 (No. A6478) because it was killed shortly after its release on 8 February 1977. It was released on the west shore of Banana River, about 1 km north of a barge canal that crosses Merritt Island, connecting Banana River and Indian River. It apparently traversed the canal because its carcass was stranded on the west shore of Indian River 3 wk later. The skull had been penetrated by a boat propeller. Cranial measurements of this 34.8 kg, 62.8 cm (CLSL) ridley are: basicranial length - 142 mm; greatest skull length -192 mm; skull width (at squamosals) - 135 mm; and mandible length - 113 mm.

The fate of Atlantic coast ridleys is not well understood. The abundance and predictable size classes of young ridleys found along the eastern North American coast to New England are such that Carr (1980) has recently revised the earlier suggestion that Atlantic ridleys are waifs that never return to the breeding population in the Gulf of Mexico (Carr, 1956). Hildebrand (1982), however, argues persuasively that the whole life history occurs in the Gulf. The 2 smaller individuals reported here were only slightly shorter than the smallest adult females reported by Pritchard (1969) and the third was well within the adult range. This is in contrast to the thoroughly juvenile composition of loggerhead and green turtle populations discussed below. It seems unlikely that these individuals could have returned to Rancho Nuevo to breed in the following spring, but a later return to the natal beach is neither suggested nor denied by these records.

On 19 January 1974, B. Thompson, E. Grosmaire and R. Snyder discovered the partial carcass of an Atlantic hawksbill turtle, *Eretmochelys*

TABLE 1. Morphometric characteristics and weights of Kemp's ridley turtles, *Lepidochelys kempi*, from the Indian River lagoon system, 1976-1981.

Number	Date	Carapace Length (cm)		Carapace Width (cm)		Plastron Length (cm)	Head Width (cm)	Weight (kg)
		straight line	over curve	straight line	over curve			
A3115	8 Sept. 1976	58.9	63.2	54.9	62.5	45.6	11.8	26.8
A6478	21 Jan. 1977	62.8	63.7	55.3	61.2	48.0	13.3	34.8
K332	14 Jan. 1981	55.0	57.3	54.1	60.3	43.7	11.3	22.7

imbricata, along the shore of Eddy Creek, at the south end of Mosquito Lagoon. The specimen consists of: 1) four posterior pleural bones on the right and left and the corresponding neurals; 2) the pygal and 3 suprapygals; 3) five posterior marginal bones; 4) both supracaudal scutes, the last marginal on the left, the posterior vertebral and the posterior costal scute on the left. All of the above are articulated and adhering. In addition there are 11 disjoined carapace and 2 marginal scutes. The skull is complete except for the columellae; the upper and lower rhamphothecae are preserved. Basicranial length of the skull is 69 mm; greatest skull length is 83 mm; skull width (at squamosals) is 47 mm; and mandible length is 60 mm. I estimate that this hawksbill was 31 cm long (CLSL) and weighed approximately 3.5 kg.

There are oceanic records of this very tropical sponge-feeding species along the east coast of North America to Massachusetts, and 2 old nesting records from south Florida (Carr et al., 1966), but no records of its occurrence in the Indian River lagoon system. The stranding site is a small cove with a constricted entrance that is a gill-netting site often used by commercial fishermen. They occasionally capture and drown small marine turtles (mostly *Chelonia*) in their small-mesh monofilament nets. It is likely that this small hawksbill died or was killed in the Eddy Creek cove rather than that it floated in through the narrow entrance.

The loggerhead turtle, *Caretta caretta*, and the green turtle, *Chelonia mydas*, continue to be the predominant marine turtle species in the system and the major aim of this study was to characterize their present-day populations. During the course of the study, 89 loggerheads and 11 green turtles were captured in the nets. The hypothermic stunning episodes provided 116 loggerheads and 188 green turtles for study. Our data base, therefore, includes information from 205 *C. caretta* and 199 *C. mydas*. The difficulty in studying these populations is seen in the fact that even in Mosquito Lagoon, which was the only lagoon where we could regularly succeed in capturing turtles, the capture rate was only 0.67 turtles per day (24 hr), or 2 turtles every 3 da. In the Indian River, we were only able to catch 2 turtles in 1637 hr of netting (0.02 captures/day) and no turtles were captured in 290 hr of netting in Banana River. Prior to 1981, we had only seen 8 turtles from the Indian River (6 were cold-stunned in 1977) and 3 from Banana River (also from the 1977 cold spell). The latter 3 represented 3 species, however: *C. caretta*, *C. mydas*, *L. kempi*. Through the first 4.5 yr of the study, then, there was no evidence for the existence of significant populations of marine turtles in any of the 3 lagoons except Mosquito Lagoon. This conclusion was difficult to accept because of the occasional carcass strandings and sitings by fishermen that were reported.

Then, in January 1981, another hypothermic stunning episode occurred that effectively dispelled the unseemly conclusion. Over a period of 7 da, 163 stunned or dead marine turtles were examined. This time there were more from the Indian River (86) than from Mosquito Lagoon (77) and the 2 species were nearly equally represented. This was the first evidence, then, of significant populations of green turtles and loggerheads in the Indian River. The status of Banana River populations remains unknown.

Mendonca and Ehrhart (1982) described the structure of *C. mydas* and *C. caretta* populations in Mosquito Lagoon in terms of the frequency distributions of weight and straight-line carapace length. They gave no account of other morphometric measurements and no means or measures of variance. The morphometric statistics summarized in Tables 2 and 3 are derived from the records of all turtles captured in all 3 lagoons, by cold-stunning or netting, through September 1981. Taken together with the size and weight distributions of Mendonca and Ehrhart (1982), they provide a morphometric characterization of the *Chelonia mydas* and *Caretta caretta* populations of the northern part of the Indian River lagoon system.

The data in Tables 2 and 3 reveal that the loggerheads of the system are about twice as large as the green turtles. This does not imply, however, that the age structures of the 2 populations differ in any marked way. It is becoming increasingly clear (Mendonca, 1979; Limpus and Walter, 1980) that loggerheads grow at approximately twice the rate of green turtles. The fundamental conclusion that can be drawn from these data is that the *Chelonia* and *Caretta* populations of the Indian River lagoon system are characteristically composed of juvenile and/or subadult animals (these 2 terms are not well defined for marine turtles). There are very few, and perhaps no adults in either population. This is especially true for green turtles. The smallest adult female of this species seen nesting on northern Brevard County beaches by Ehrhart (1980) measures 88 cm (CLSL); the

TABLE 2. Summary of carapace length and width measurements of green turtles, *Chelonia mydas*, and loggerhead turtles, *Caretta caretta*, from the Indian River lagoon system, 1976-1981.

	Chelonia mydas N:199	*Caretta caretta* N:205
Straight Line		
Length (cm)		
$\bar{x}$	48.2	65.8
(S.D.)	(13.7)	(8.9)
Range	25-74	44-93
Width (cm)		
$\bar{x}$	38.3	53.4
(S.D.)	(10.6)	(6.2)
Range	19-59	39-73
Over Curve		
Length (cm)		
$\bar{x}$	51.6	71.4
(S.D.)	(14.5)	(9.5)
Range	26-82	49-100
Width (cm)		
$\bar{x}$	44.9	66.4
(S.D.)	(12.9)	(8.3)
Range	23-72	48-94

TABLE 3. Summary of weight, plastron length and head width measurements of green turtles, *Chelonia mydas*, and loggerhead turtles, *Caretta caretta*, from the Indian River lagoon system, 1976-1981.

		Weight (kg)			Plastron length (cm)			Head width (cm)		
Species	N	Range	$\overline{x}$	(S.D.)	Range	$\overline{x}$	(S.D.)	Range	$\overline{x}$	(S.D.)
Chelonia mydas	199	2-59	18.8	(1.0)	21-64	41.2	(11.5)	3-11	7.0	(1.9)
Caretta caretta	205	13-111	43.7	(17.7)	21-67	50.9	(6.8)	8-20	13.7	(2.1)

largest seen in the lagoon was 74 cm. Mendonca and Ehrhart (1982) noted that about 5% of the loggerheads were "likely" to be mature, but there is undoubtedly so much variation in size at maturity that the percentage could be even smaller.

The existence of these populations of immature loggerheads and green turtles in the Indian River lagoons constitutes a good demonstration of the "developmental habitat" component of the model for marine turtle ecologic geography of Carr et al. (1978). A similar population of immature green turtles occurs in the Cedar Key-Crystal River area of the Florida Gulf coast (Carr and Caldwell, 1956). An aggregation of young green turtles that may also be comparable is well known to fishermen in Pamlico Sound, off North Carolina, where they are known as "lady turtles" (A. Carr, pers. comm.). These results suggest that many of the turtles, especially green turtles, spend the early postpelagic years in bays and lagoons, but move to one or more other habitats before maturing.

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Academy Symposium

FREQUENCY DISTRIBUTION PATTERNS AND PARTITIONING OF COPPER, IRON AND ZINC IN SELECTED TISSUES OF THE BLACK MULLET (*MUGIL CEPHALUS*)

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ABSTRACT: *Copper, iron and zinc concentrations were determined for muscle, gill and liver tissue from 45 black mullet* (Mugil cephalus) *collected in Turkey Creek, an embayment of the Indian River Lagoon, Florida. In the liver, Fe concentrations (2420 ± 1040 μg/g, dry wt) were higher than for Cu (510 ± 350 μg/g) and Zn (330 ± 120μg/g). Gill tissue iron levels (380 ± 140 μg/g) were greater than those for Zn (96 ± 26 μg/g) and Cu (6.3 ± 4.4 μg/g). Muscle tissue concentrations were lowest with Fe values (19 ± 15 μg/g) greater than those for Zn (13.5 ± 4.9 μg/g) and Cu (1.1 ± 1.6 μg/g). Significant correlations were observed for Cu, Fe and Zn in the gills, and Fe and Cu, and Fe and Zn in the liver. Metal concentrations generally did not covary with whole fish wt or length. Cu, Fe and Zn in the muscle and Cu in the gills show differing degrees of non-normal, positive skewness.*

COPPER, Fe and Zn are trace metals required by many organisms. The margin between need and tolerance for these metals is often small. Bowen (1966) believes that these elements have a high potential as pollutants due to the improper discharge of metal-laden wastes. Biota, including man, are the ultimate victims of such improprieties. Thus, environmental scientists are challenged to understand the fine line that may separate metal need from stress in aquatic organisms. This study examines the distribution of Cu, Fe and Zn in black mullet (*Mugil cephalus*) from the Indian River Lagoon, Florida, to evaluate natural variability in tissue metal concentrations, and establish a baseline for identifying perturbations due to pollution.

Black mullet are an abundant and commercially important fish. From

1972 to 1975, commercial fishermen in Florida brought in a yearly average of 12,500 metric tons of mullet with an annual value of $3,466,000 (Prochaska and Morris, 1978). Mullet are also an important food source to aquatic predators such as sea trout and porpoises. Mullet travel in large schools and are often found in bays, lagoons and other sheltered waters. They are found in both the freshwaters of the St. Johns River, Florida, and the saline waters of the Indian River Lagoon (Jordan and Everman, 1969).

Mullet, like most other aquatic organisms may assimilate metals well above environmental levels. They do so via ingestion of suspended particulates, ion exchange, consumption of food, and adsorption on tissue and membrane surfaces (Phillips and Russo, 1978). When metal levels are extremely high in the environment, accumulation may be to lethal doses. Because the sediments are the major sink for most pollutants introduced into aquatic systems, the omnivorous benthic feeding habits of mullet make them vulnerable to sediment and water contaminants. Establishing trace metal concentrations in selected tissues of *Mugil cephalus* is thus important because mullet are utilized as a food source by man and other fish and because their habitats and feeding habits make them susceptible to coastal zone pollutants.

STUDY AREA—The 45 mullet analyzed herein were collected at the mouth of Turkey Creek (Fig. 1). Turkey Creek receives discharges from a secondary wastewater treatment plant, the leaching of anti-fouling paints from boats in local marinas, effluents from a semi-conductor manufacturing facility, and non-point runoff from local municipalities.

Recent studies of trace metals in Turkey Creek (Wieckowicz, 1980) suggest instances of elevated concentrations of Cd, Cu, Ag, Cr and Zn. Barber and Trefry (1981) showed measurable Cu pollution in the barnacles and

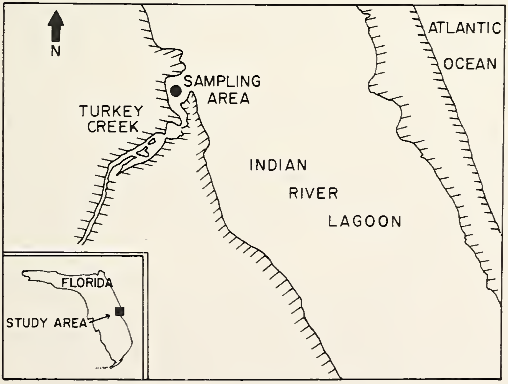

FIG. 1. Map showing location of Turkey Creek sampling area.

water of the Eau Gallie Harbor, another nearby Indian River embayment. However, this Cu perturbation was not observed in the open Indian River. Steward (1980), investigating Cu and Fe in Indian River clams, water and sediments also concluded that the concentrations of these metals were at natural levels in the open estuarine system.

Methods—Mullet were collected in the Fall of 1979 and the Spring and Summer of 1980 using gill and cast nets. Immediately after sampling, whole fish were placed in plastic bags and set on ice. Fish were weighed to the nearest 0.1 g and then frozen until dissection.

All dissections, digestions, and dilutions were performed in a clean lab where standard apparel included a lab coat, non-talced polyethylene gloves, a cap, and plastic shoe covers. The clean lab is separated from the main lab by double doors and is serviced with HEPA filtered air. Throughout the study, extreme care was taken to minimize random contamination.

Mullet were dissected in a Class 100 laminar flow hood. Whole gills (from the left side), complete livers, and from 2 to 8 g (wet wt) of muscle tissue were removed from each specimen. Scalpels were rinsed with dilute HNO_3 and distilled water following each incision and used for only one fish. Individual fish tissues were placed in acid-washed, 180 ml "tall form" beakers and freeze dried for 36 hr to determine sample dry wt. Ten ml of redistilled HNO_3 were then added to each sample and blank. The beakers were covered with a watch glass and refluxed for 8 hr at 120°C in a clean room fume hood. The watch glasses were then removed briefly as the samples were evaporated to about 5 ml. Three ml of redistilled $HClO_4$ were then added to each sample to oxidize any remaining organic matter. The watch glasses were then replaced on the beakers, and this mixture was heated until it became clear. Finally, the watch glasses were removed and the samples evaporated to 2 ml. Liver samples were diluted to 250 ml with distilled-deionized water. Gill and muscle digests were diluted to 25 ml. In most cases, Cu could be analyzed in these solutions. For Fe and Zn, 1 ml of the liver and gill digests was diluted to 10 ml.

The digest solutions were analyzed by flame atomic absorption spectrophotometry using a Perkin Elmer 460 instrument and following the manufacturer's specifications. Atomic absorption analysis sensitivities for this work (expressed as ppm metal to give 1% absorption, which is 0.0044 absorbance) were: Cu, 0.1 ppm; Fe, 0.15 ppm; and Zn, 0.02 ppm. Procedural blanks obtained for this study were as follows: Cu, 0.03 ppm; Fe, 0.09 ppm; and Zn, 0.04 ppm. The reliable detection limits for mullet tissue based on tissue wt, dilution factors and analytical sensitivities for the metals in solution were: Cu, 0.4 μg/g; Fe, 3.0 μg/g; and Zn, 0.4 μg/g.

To check analytical accuracy, National Bureau of Standards oyster tissue (Standard Reference Material 1566) was analyzed. The reference material was freeze-dried, digested and diluted in the same manner as the samples. The experimental results and the certified values are in Table 1. The observed mean values of Cu and Fe fall within the certified range. The mean value for Zn was higher than expected, yet within 6% of the NBS value. Contamination does not appear to have been a factor in this Zn difference because the procedural blank values were low relative to sample absorbances.

To check precision, mullet tissue was analyzed in triplicate. After freeze-drying, liver, gill and muscle tissue were homogenized by powdering with a glass rod. Each sample was then divided into ca. equal portions. Three samples were analyzed and the results (Table 1) show precisions to be quite acceptable.

A third quality control check involved spiking tissue samples with known amounts of metals to measure percentage recovery during digestion. Spikes varied as a function of tissue and metal so as to provide an addition of about the same magnitude as the metal content of the original sample. The following spike ranges were thus used; Cu and Zn, 100 to 500 μg; Fe, 100 to 2000 μg. The spike recoveries avg 98% (Table 1) and show that little or no metal was lost (or gained) during the digestion procedure.

Results and Discussion—Copper, Fe and Zn concentrations for liver, gill and muscle tissue of *Mugil cephalus* from this study are in Table 2. The mean value for Cu is reported as <1.1 μg/g because eight of the samples were below the 0.4 μg/g detection limit for this study. Significant variability in metal concentrations was found for each of the organs as shown by the large standard deviations and ranges. Large ranges are not uncommon in

TABLE 1. Results of NBS oyster tissue (SRM 1566) analysis, and precision evaluation and metal recovery tests for *Mugil cephalus* (mean values with standard deviations; concentrations in μg/g dry wt). Percentage calculated by: $\frac{\text{observed (tissue value + spike)}}{\text{calculated (tissue value + spike)}} \times 100$ using samples from the same tissue pool used for the replicate analysis checks. Variations in percentage recovery are subject to variations implicit in the standard deviations of the replicate study.

	Cu	Fe	Zn
NBS Certified oyster values	63.0 ± 3.5	195 ± 34	852 ± 14
Experimental oyster values (This study, N = 3)	64.0 ± 1.7	183 ± 3	901 ± 32
Replicate analyses (N = 3)			
Gills	3.6 ± 0.2	335 ± 11	94 ± 2
Liver	69.0 ± 2.6	789 ± 83	266 ± 10
Muscle	0.8 ± 0.2	24.0 ± 2.5	11.0 ± 0.6
Results of spiking experiment *(Values expressed as % recovery)*			
Gills	99	94	103
Liver	105	92	97
Muscle	96	98	Not available

TABLE 2. Means, standard deviations, ranges and medians for Cu, Fe and Zn in muscle, gill and liver tissue from *Mugil cephalus* specimens collected in Turkey Creek, Florida (Values in μg/g dry wt; Number of samples = 45).

Metal	Statistical Parameter	Muscle	Gills	Liver
Cu	Mean	< 1.1	6.3	510
	Standard Deviation	1.6	4.6	350
	Range	0.4 to 11	1.5 to 25	29 to 1860
	Median	0.8	4.8	420
Fe	Mean	19	380	2420
	Standard Deviation	15	140	1040
	Range	6.5 to 62	42 to 820	430 to 5560
	Median	12	390	2540
Zn	Mean	13	96	330
	Standard Deviation	5	26	120
	Range	7.6 to 31	31 to 160	95 to 650
	Median	12	93	340

trace metal studies of fish (Montgomery et al., 1976; Murphy et al., 1978). For example, Murphy et al., (1978) found sample standard deviations often to be as large as sample means in a study of the Cu, Cd, and Zn content of fish.

Highest Cu, Fe and Zn levels were consistently found for liver tissue with an overall trend of liver > gills > muscle. In the muscle and gills, Fe was highest followed by Zn, then Cu. In the liver, Fe was again the highest, but this time was followed by Cu and then Zn.

Previous data on muscle Cu and Zn concentrations for *Mugil cephalus* from the Indian River and other Florida locations are in Table 3. Within the observed concentration ranges, the Cu data in Table 3 are similar; however, Zn levels in the Turkey Creek samples are noticeably higher.

TABLE 3. Cu and Zn concentrations in the muscle tissue of *Mugil cephalus* from Turkey Creek and other Florida locations (Metal concentrations in μg/g dry wt). Asterisk indicates data from Cato and McCullough (1976).

Area	No. of Samples	Zinc Mean	Zinc Range	Copper Mean	Copper Range
Turkey Creek (This study)	45	13.4	7.6 to 31	<1.1	<0.4 to 11
Atlantic Ocean (Oak Hill, FL)*	10	5.2	2.9 to 12.6	0.7	0.4 to 2.4
Indian River Florida*	16	5.8	3.4 to 10.7	0.4	0.2 to 0.8
Gulf of Mexico (Panama City, FL)*	10	6.4	4.3 to 16.6	0.3	0.2 to 0.5
Naples, Florida*	18	5.0	1.4 to 6.8	0.3	0.2 to 0.7
West Coast Florida*	10	5.7	3.9 to 7.8	0.3	0.2 to 0.4

Metal concentrations of the various organs were compared with each other and with individual mullet length and wt. Most of the correlations were not statistically significant at the 95% confidence level ($p = 0.05$). Natural variations in trace metal levels in this population of black mullet may partly account for this observation. In the liver, significant correlations (at $p = 0.05$) were observed between length and Zn ($r = 0.34$) and Cu ($r = 0.38$) concentrations. This may indicate a sequestering of these metals in this organ with age. McFarlane and Frazin (1980) also observed increasing levels of Cu with age in northern pike. All correlations involving Cu, Fe and Zn in the gills are positive and significant (at $p = 0.05$; for Cu/Fe, $r = 0.36$; Cu/Zn, $r = 0.59$; Fe/Zn, $r = 0.42$) and suggest that these metals follow similar metabolic pathways in the gills. Significant correlations ($p = 0.05$) also were observed between Cu and Fe ($r = 0.43$) and Fe and Zn ($r = 0.61$) in the liver showing that these required trace metals also covary in this organ.

Concentrations of essential elements such as Cu, Fe and Zn are internally controlled and regulated at optimum levels. Giesy and Wiener (1977) note that such homeostatic control of required trace metals should lead to normal distribution of these elements in fish tissue. Histograms of Cu, Fe and Zn in the muscle (Fig. 2), gills (Fig. 3), and liver (Fig. 4) were constructed to graphically evaluate trace metal distribution patterns in mullet. Most of these graphs are characterized by having one or more values on the extreme right (high side) of the x-axis (concentration), resulting in a skewed distribution. These distributions were statistically tested for skewness using Fisher's equation:

$$g_1 = m_3/(m_2 m_2) \tag{1}$$

where

$m_3 = \Sigma(x-\bar{x}^3)/n$

$m_2 = \Sigma(x-\bar{x}^2)/n$

x = individual metal-organ concentrations

$\bar{x}$ = mean metal-organ concentrations

n = number of observations

(for $N = 45$, $p = 0.05$, if $g_1 > 0.56$, the skewness is significant)

The results show that all the data sets exhibit positive skewness; however, the skewness values were not statistically significant (g_1 values were $\leqq 0.33$ at $p = 0.05$) except for Cu in the muscle ($g_1 = 2.2$).

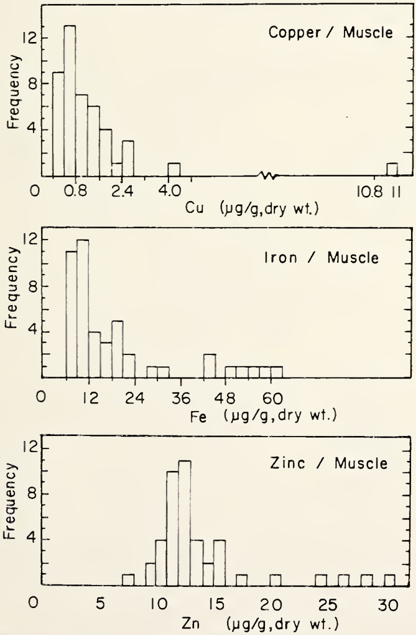

FIG. 2. Frequency histograms showing the distributions of Cu, Fe and Zn in muscle tissue from the black mullet (*Mugil cephalus*). Units are $\mu g\ g^{-1}$ (dry wt).

The extreme concentrations in Figs. 2, 3 and 4 may incorporate naturally occurring variations in the populations or represent perturbations induced by pollution. Giesy and Wiener (1977) note that a positive skewed distribution results from a positive skewness of a given metal in the environment. However, even though the high values may inflate the mean, they should not be disregarded because they may provide a useful tool for monitoring human health hazards in the fisheries industry.

The chi-square goodness of fit test was also applied to the metal data for each organ. Four of the 9 metal/organ data sets fit a normal distribution (both Fe and Zn in the gills and liver). The possibility that the tissue metal data fit $\log_{10}$ normal distributions was also investigated following the suggestions of Ting and de Vega (1967). Interesting enough, the 4 normally

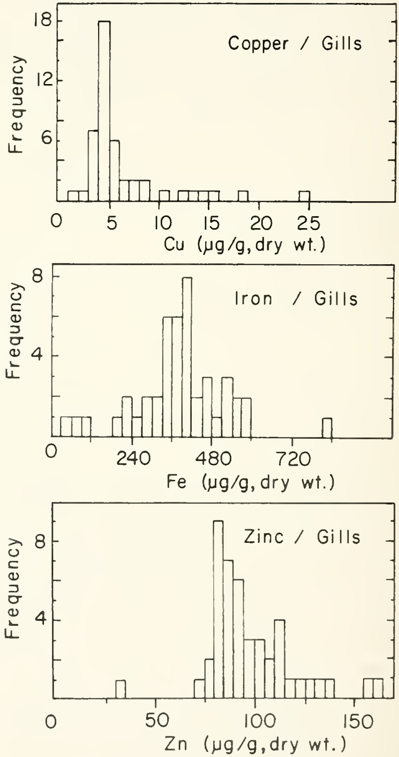

FIG. 3. Frequency histograms showing the distributions of Cu, Fe and Zn in gill tissue from the black mullet (*Mugil cephalus*). Units are μg g^{-1} (dry wt).

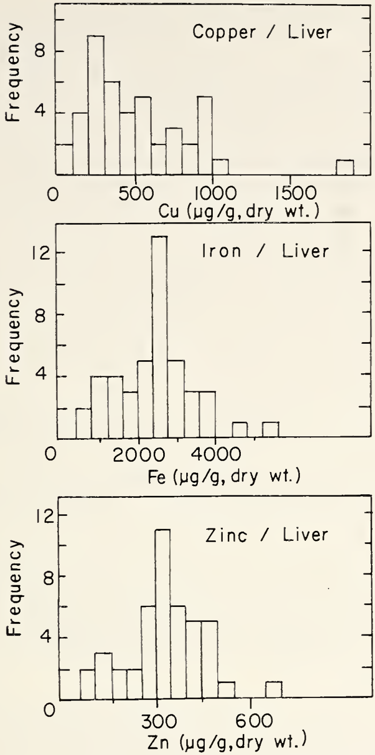

FIG. 4. Frequency histograms showing the distributions of Cu, Fe and Zn in liver tissue from the black mullet (*Mugil cephalus*). Units are $\mu g\ g^{-1}$ (dry wt).

distributed frequencies plus Cu in the liver followed the log-normal goodness-of-fit test at $p = 0.05$. Copper concentrations in the muscle and gills, and Fe and Zn data for the muscle did not conform to either distribution. The non-normal distribution of the 3 metals in muscle tissue may indicate that regulation of metal levels in mullet muscle is not under rigid internal control or that the observed high values may be pollution related.

Those mullet with high levels of Cu and Zn in the organs investigated are possibly being subjected to a pollutant stress. Higher than background levels of Cu and Zn have been observed in restricted Indian River embayments (Barber and Trefry, 1981). Turkey Creek, located about 10 km south of the Eau Gallie River (investigated by Barber and Trefry, 1981) also receives fresh water from inland sources. Both areas are subject to inputs from non-point runoff, secondary sewage treatment plant effluent, and the leaching of Cu containing anti-fouling paints from boat hulls. Barber and Trefry (1981) found concentrations of Cu and Zn to be highest in barnacle soft tissue in the area of the Eau Gallie Harbor, which is surrounded by marinas. Dissolved Cu in the water column was also highest at this point suggesting that this biologically available Cu originates from the leaching of anti-fouling paints.

Mullet who frequent such embayments may come into contact with restricted areas of higher than normal metal levels. Due to their migratory nature, mullet remain in one area for only a short time. However, even short term exposure may cause an increase in internal metal content. Sullivan (1980) reported that blue crabs captured in the Eau Gallie Harbor contained 25 ± 10μg/g (wet wt) of Cu in the gonads, whereas crabs from the open waters of the Indian River Lagoon had significantly lower concentrations of 11 ± 7 μg/g in this tissue. Copper in the flesh averaged 15 ± 9 μg/g for the Eau Gallie Harbor crabs and was not statistically different from values for crabs collected in the open estuary (9 ± 4 μg/g).

The data collected for mullet in this study provide a baseline of present-day levels of Cu, Fe and Zn in the muscle, gills and liver of *Mugil cephalus* from the Indian River Lagoon, Florida. Mullet are widely used as a human food source and thus monitoring programs for potential pollutants are important. The implication of subtle metal contamination in mullet presented here serves to initialize concern for the health of the Indian River system. Because metals can biologically accumulate, their continued uncontrolled input into this system could pose an environmental hazard. The data base generated in this study provides a useful reference for future studies of metals in mullet and delineates the natural variability of metal concentrations in this organism.

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Academy Symposium

USE OF AERIAL IMAGERY IN DETERMINING SUBMERGED FEATURES IN THREE EAST-COAST FLORIDA LAGOONS

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ABSTRACT: *Low altitude aerial photography coupled with groundtruthing, was used to delineate seagrass beds, oyster bars, and other shallow water (<2.5 m) features in 3 contiguous east-coast Florida lagoons. Imagery analysis was used to produce maps, representing 182 km² of grassbeds, 10km² of oyster bars, and 16 km² of dredged areas. Five areas, in 3 contiguous lagoons, were photographed in the spring of 1974 and winter of 1975. The areas and time of year were selected because of increased water clarity. Direct examination of color infrared transparencies over a light table proved to be the most effective method for delineation of submerged features.*

THE Indian and Banana rivers and Mosquito Lagoon comprise Brevard County's major estuarine water systems (Fig. 1). They lie east of a coastal ridge, and are separated from the Atlantic Ocean by an extensive system of barrier islands. They are shallow, non-tidal, eoline mixed, saline lagoons that have a depth range of 0 to 4 m, except in portions dredged for boat traffic.

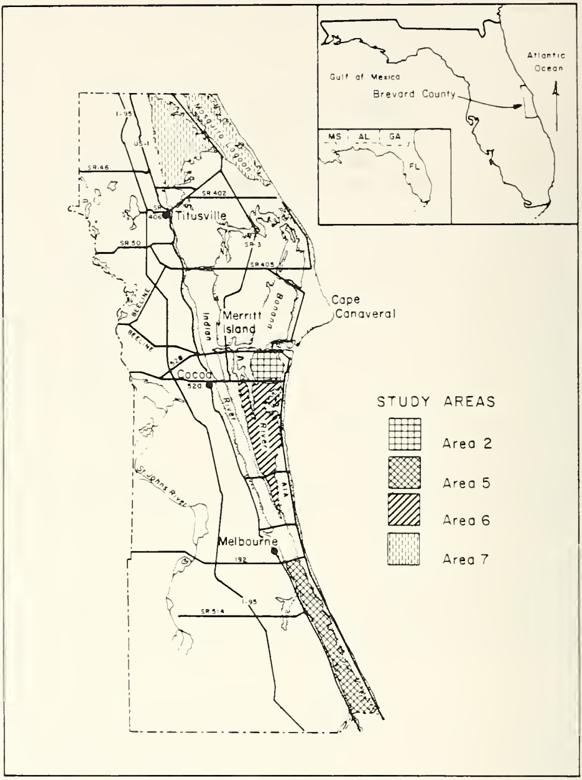

Fig. 1. Area map detailing study areas.

Preliminary investigations indicated the bottom flora within the lagoons range from shallow seagrass beds dominated by manatee grass (*Syringodium filiforme*) and/or Cuban shoalweed (*Halodule wrightii*), to deeper areas (>3.0 M) dominated by 2 species of drift algae (*Gracilaria blodgettii* and *Hypnea cornuta*).

Seagrass beds are valuable to estuarine ecosystems (Wood et al., 1969 and Thayer et al., 1975). Considerable effort has been expended to determine seagrass distribution. Recent efforts have focused on remote sensing techniques as a tool to reduce the labor expended to map seagrass areas and other features (Kolipinski and Higer, 1969; Thompson, 1972; and Sowers, 1973).

Brevard County Environmental Engineering proposed that a remote sensing study be initiated to produce maps showing grassbeds, oyster bars, and other submerged features within selected areas of the Indian and Banana rivers and Mosquito Lagoon.

Methods and Materials—Four areas were selected for imagery analysis based on the State of Florida surface water classification. Areas 2 and 6 are classified as aquatic preserves, and 5 and 7 as shellfish harvesting areas (Fig. 1). Based on past water quality data collected in the 3 lagoons, (unpubl. data, Brevard County Health Dept.), these areas have clearer water than other portions of the lagoons. Chlorophyll *a* values collected monthly from 1968 to 1974 showed decreases in primary production during winter and early spring. Thus, with increased light penetration due to decreased scattering effects, submerged features could be distinguished with aerial imagery at greater depths during these seasons.

Color and infrared aerial imagery was obtained with a NASA-6 aircraft (twin engine Beechcraft) with cameras mounted on the bottom. The first flight, in March of 1974, was flown at an altitude of 1.8 km with a KA-2 camera and a 15.25 cm dia camera lens. The second flight, in January of 1975, was flown at an altitude of 3.7 km with a Zeiss camera and a 30.5 cm dia camera lens. Flights were planned for days with less than 15% cloud cover and winds of less than 16 km/hr. The aircraft speed was 231 to 277 km/hr. The spring and summer season sun angle requirements were 30 to 50°, with a much wider allowance in the winter season.

The IR color film was Kodak Infra-Red Aerial-graphic film, type 2443. Because this film was blue-sensitive, filters were used for red, green, and infrared expression (Wratten 12 or 15). The imagery scale was 1:12,000 and the final film products were processed into 23 × 23 cm transparencies.

Several imagery analysis systems were compared, but gave limited results in the areas studied. An Image 100 system was coupled with a microdensitometer and information stored on magnetic tape. The enhanced data were then displayed real-time on a Digicol CRT.

Another method used for photographic interpretation was the 1^2S viewing system. The system utilized a 4 channel optical system that could add "false colors" to black and white images. Both the Image 100 and 1^2S systems were less accurate than the method of direct examination of infrared transparencies with groundtruthing comparisons.

Groundtruthing was performed by collecting all seagrasses and algae in 10 m^2 grids placed at random along selected transects in water less than 1.5 m. All seagrass and algae samples were removed at the sediment surface. Light diving gear was used in some cases for collection of seagrasses and algae. The waterward extent of seagrass coverage was determined by sampling with an Ekman dredge placed randomly along each transect. Seagrass and algae samples were preserved in 5% formalin for laboratory identification. No attempt was made to correlate seagrass biomass to imagery analysis.

Results—Color IR transparencies proved to be the most effective aerial photographic method for detecting submerged features. The following features were detected by direct examination of the color IR transparencies by transmitted light over a light table (Table 1): 1) Seagrass beds to a max-

Table 1. Submerged features in study areas.

	Seagrasses		Types of Sea–Grasses[1]					Shellfish		Canals	
Area	Acres	Km²	Rm	Dw	Sf	He	Tt	Acres	Km²	Acres	Km²
2	4448	18.0	x	x	x	x	-	-	-	257.3	1.0
5	6674	27.0	x	x	x	x	x	2509	10.1	-	-
6	8521	34.5	x	x	x	x	-	-	-	3491.0	14.1
7	25211	101.8	x	x	x	x	-	-	-	319.4	1.3

[1] Rm = *Ruppia meritima*, Dw = *Diplanthera wrightii*, Sf = *Syringodium filiforme*, He = *Halophila engelmannii*, and Tt = *Thalassia testudinum*.

imum depth of 2.5 m, 2) Dredged areas and residential canals, 3) The Intracoastal Waterway channel, 4) Oyster bars and rocky areas in depths to 1.5 m, and 5) Sandbars.

The following features were detected by inference (i.e., if *A* and *B* always occurred together during groundtruth investigations, then when only *A* was detected on the transparencies, *B* was assumed to be present also): 1) Rocky areas and associated substratum specific seaweeds, and 2) Certain bottom configurations and oyster bars.

Field investigations revealed that the major seagrass species, in areas of gently sloping sand bottoms, occurred in 3 zones that were usually associated with a depth range. The zones did not show a sharp transition from 1 dominant species to another, but rather, they showed a slow gradation from 1 species to another. The following is a brief description of these zones.

Zone 1: 0 to 0.5 m. Usually free of vegetation due to a buildup of decaying seagrasses deposited into windrows. The seagrass *Ruppia maritima*, however, was present in low salinity areas of the lagoons when windrows were absent.

Zone 2: 0.5 to 1.5 m. Usually dominated by *Halodule wrightii*.

Zone 3: 1.5 to 2.5 m. Usually dominated by *Syringodium filiforme*.

The above water depths were correlated to the maximum aerial imagery depth. Seagrasses did occur below 2 m in each area, but were not mapped.

The following are brief descriptions of each study area based on aerial imagery and groundtruth data (Fig. 2-5).

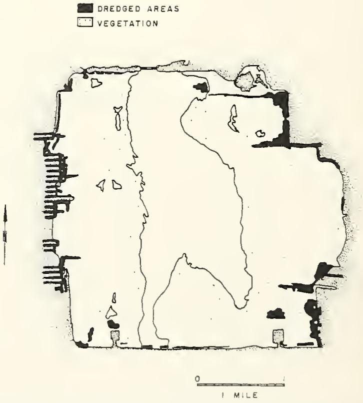

FIG. 2. Aerial imagery map of submerged vegetation and dredged areas in Area 2.

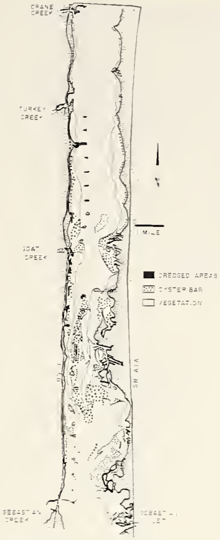

FIG. 3. Aerial imagery map of submerged vegetation, oyster bars and dredged areas in Area 5.

Area 2: The seagrasses *Ruppia maritima* and *Halodule wrightii* exhibited a typical zone pattern extending to a water depth of 0.5 m to 1.5 m, with *R. maritima* bordering the shallower, lower salinity areas. Typically, *R. maritima* was not as dense as other grasses, and usually appeared in late May and disappeared in August or September.

In this study area, the next zone was dominated by *Halodule wrightii* followed by *Syringodium filiforme* to a maximum imagery depth of 2.5 m.

Area 5: As in Area 2, *R. maritima* appeared seasonally in the 0 to 0.5 depth zone; the *H. wrightii* - *S. filiforme* zones extended from 0.5 m to 2.0 ± m. A fourth seagrass, *Thalassia testudinum*, was found in a small area just north of Sebastian Inlet.

Water along the eastern shoreline generally had better clarity than did the western shoreline. The increased visibility on the east shoreline was possibly related to increased nutrient uptake by the extensive seagrass beds, which in turn, limited phytoplankton concentrations. The deep areas, including the Intracoastal Waterway channel, appeared uniformly dark on the color IR transparencies.

The Intracoastal Waterway channel often had no obvious photographic boundaries, except where the borders consisted of seagrasses. Oyster bars in water to a maximum depth of 1.5 m appeared as small, semi-circular dark patches against the lighter background of sand bottoms.

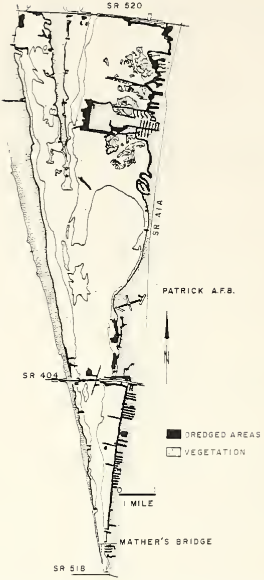

Fig. 4. Aerial imagery map of submerged vegetation and dredged areas in Area 6.

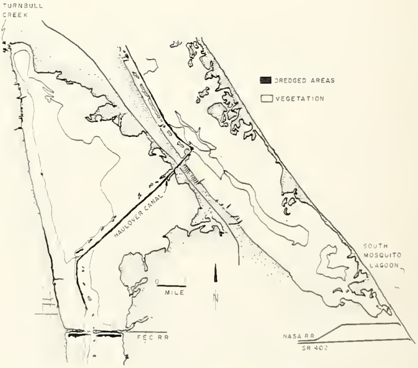

Fig. 5. Aerial imagery map of submerged vegetation and dredged areas in Area 7.

Area 6: The dominant seagrasses in this area exhibited the typical zone pattern that was observed in other areas to an imagery depth of 2.0 m. A fourth seagrass, *Halophila engelmanii*, was found growing in small patches that did not appear to be related to water depth.

Fifty-one species of algae were found in this area and appeared to be highly seasonal with the greatest abundance occurring in summer (33 rhodophytes and 18 chlorophytes).

Area 7: Dense stands of the seagrass *H. engelmannii*, constituted a unique feature of this area. Pure stands of *H. engelmannii* were found in patches exceeding $20m^2$, but it was usually growing with *H. wrightii* and *S. filiforme*. In this area, *H. engelmannii* appeared to be neither depth nor substratum specific. The *R. maritima*, *H. wrightii* and *S. filiforme* zones were similar to the other areas.

Groundtruth data were compared with data analyses using the Digicol and the Image 100/microdensitometer system. The most important factor in obtaining useful information was water turbidity.

At a depth of 1 m, the Digicol distinguished grassbeds and quantified them, but at a depth of 2 m it could not separate grassbed densities from depth densities. The microdensitometer slicing technique was successful in separating these densities in Area 2, but it did not work in Area 5.

The IM 100 had limited data analysis capabilities with the aerials because of the minimum area pixel requirements (one acre). Like the Digicol, the signatures for oyster bars and grassbeds were only developed after extensive experimentation. Applying IM 100 data to different areas of the 3 lagoons met with mixed results.

Although underwater features were visible on Kodachrome color aerial transparencies, their delineation to the unassisted eye, as well as with the instruments used, was less clear when compared with other films. Because the underwater signature was dependent on light penetration through the water column, better results could be obtained with Kodachrome color film in areas with less primary production. The best use of these color transparencies, however, may be for detection and documentation of emergent vegetation in wetlands, rather than for underwater features.

The color infrared transparencies proved to be the most effective method for detection and documentation of submerged features (Table 1). All maps were produced by direct examination of transparencies over a light table.

Discussion—The use of aerial imagery was considered the best available method for mapping underwater features in shallow areas of the lagoons. The savings in manpower, boat and equipment use, and field time made the use of aerial imagery more cost effective than conducting field investigations alone. Distortions in the final product did, however, present problems.

Distortions produced by tilting and altitude changes of the aircraft presented problems, but were kept to a minimum by scheduling flights for good weather conditions. In addition, the long straight flights over water were difficult to follow. The water areas should be distinguished by anchored markers to aid the pilot in navigation. If economically feasible, a 60% imagery side overlap would compensate for flight path deviations.

The quantitative and qualitative documentation of underwater features should be a basic goal of the continuing environmental assessment of surface waters. Once fully documented, these features need to be monitored so that alterations to the system can be detected and evaluated. A continuing program of remote sensing monitoring as a followup to initial studies is highly recommended and should include experiments designed to correlate seagrass biomass and speciation with aerial photographic information.

ACKNOWLEDGMENTS—This study was made possible, in part, by Dick Withrow, project manager, NASA, Kennedy Space Center, Florida (Project No. 0673). Other NASA officials whose assistance was greatly appreciated were Reed Barnett and Phil Clayborne of the Sciences, Technology and Applications office.

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SEAGRASS BEDS VERSUS SAND BOTTOMS: THE TROPHIC IMPORTANCE OF THEIR ASSOCIATED BENTHIC INVERTEBRATES

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Abstract: *Seagrass beds in the Indian River lagoon, Florida, had 3 times the density of macrobenthic invertebrates found in unvegetated sediments a few meters away. Epifaunal abundance was 13 times greater in seagrass than sand. Most epifaunal species (e.g., amphipods, isopods, tanaids, gastropods and shrimps) were uncommon in the unvegetated sediments, presumably due to their dependence on seagrass for providing habitat, food, nursery area, and/or protection from predators. Not only were macrofaunal densities much higher in natural seagrass than in sand, those animals which were more abundant (primarily the epifauna) were also more heavily preyed upon and thus are trophically more important than infauna. Four 3-mm mesh cages were set up, each within a larger 12-mm mesh cage, 2 in seagrass and 2 in sand to test 1) the importance of associated macrobenthos to the local food web and 2) the effect of small decapod predators. After 2 mo the inner cages had the lowest macrobenthos density and the highest density of decapod crustaceans, the animals we intended to exclude. The only animals more abundant in the inner cages were the decapod crustaceans. Because cages with mesh sizes even smaller than 3 mm do not effectively exclude many crustacean predators, we conclude that it is nearly impossible to exclude predators from local seagrass meadows. The grazing epifauna of seagrass meadows forms a major trophic pathway to higher predators via the decapods; such a pathway is lacking in sand bottom communities.*

The role a species plays in a community is often investigated by excluding or enclosing that species with mesh cages. In previous experiments investigating the role of predation on macrobenthos, cages apparently provided refuge for decapod crustaceans, which prey on other macrobenthos (Young et al. 1976; Arntz, 1977; Young and Young, 1977, 1978; Virnstein, 1977, 1978, 1979). Aware of these problems (Virnstein, 1978), we attempted to demonstrate both the problems of caging and the importance of small decapod crustaceans as predators on macrobenthos. The rationale was to allow decapods access into a large-mesh (12 mm) outer cage while excluding them from a small-mesh (3 mm) inner cage. Macrobenthos densities were thus expected to decrease in the outer cage and increase in the inner cage. Such experiments, done both in a seagrass bed and on a bare sand bottom, should demonstrate the relative importance of predators in these 2 habitats and, conversely, the relative trophic contributions of seagrass and sand communities to the Indian River system. We characterize and compare the macrobenthos (animals > 0.5 mm) of seagrass and bare sand habitats and contrast the relative contribution of these communities to the local food web.

Study site—Extensive seagrass meadows interspersed with bare sand patches are prominent features of the Indian River lagoon. Thompson

(1976, 1978) estimated only 2% of the lagoon bottom was covered with seagrasses. However, this overall estimate may be far too low, as seagrass coverage at some locations is 2-3 times greater (pers. obser. and mapping) than indicated on Thompson's (1976) maps. The study site (27°33.35′N, 80°20.61′W) was 2.1 km north of the Link Port canal, 9.0 km south of Vero Beach and east of the Intracoastal Waterway near Round Island. At this site there was a large (∿ 10 × 50 m) sand patch within extensive seagrass meadows: *Thalassia testudinum* and *Halodule wrightii* were dominant, with some *Syringodium filiforme* present. During the April-June study period, water depth was 12 to 73 cm, salinity 32 to 36 ppt and water temperature 28 to 30°C.

METHODS—Cages 2 × 2 m were constructed of 12-mm mesh affixed to 4 metal fence posts. Within each of these cages were 1.4 × 1.4-m cages of 3-mm mesh. Two complete sets of cages (inner plus outer) were set up in the seagrass and 2 sets in the sand, 15 m away. Thus, there were 4 "outer" and 4 "inner" cages, each enclosing an area of 2 m^2. The lower edge of all cages was buried 10 cm below the sediment surface. The upper edges of the cages extended 1 m above the bottom, and, because maximum water depth was 0.7 m, the cages were topless. Cages were set up during the period 27 April to 2 May 1978 and sampled after approximately 1 and 2 mo, on 22 May and 27 June. The adjacent natural uncaged sand and seagrass were sampled initially on 25 April as well as on the same dates that cages were sampled.

Samples were taken with a post-hole type sampler which removes a sediment core 15 × 15 × 15 cm along with any overlying seagrass and animals, which are retained by 0.5-mm mesh covering the top. A sample consisted of 4 replicate cores from each habitat—2 from each cage—to account for variation between cages (Virnstein, 1978). Two control samples were taken from the natural bottom near each of the 4 sets of cages. Samples were sieved on a 0.5-mm mesh sieve, relaxed in 0.3% propylene phenoxytol in seawater (McKay and Hartzband, 1970), fixed for 24 hr in 10% formalin in seawater with the vital stain rose bengal added (Mason and Yevich, 1967), then transferred to 70% ethanol for storage. Samples were sorted under a dissecting microscope, and retained animals were identified to lowest possible taxon.

Maintaining the cages was a problem. To remove algae and other fouling organisms from the cage mesh, cages were scrubbed with a stiff brush after 1 wk, then subsequently twice a week. Initially, after the cages had been set up, we attempted to remove all predators by dipnetting each inner cage repeatedly (20-30 times) until no further fishes or decapod crustaceans were removed in the last 4-6 sweeps. Each time the cages were scrubbed, whatever predators were visible were carefully dipnetted out.

After the final core sampling of the macrobenthos on 27 June, the entire area of each of the cages was dipnetted repeatedly to check whether we and the cages had been successful at removing and excluding predators. To determine what predators had recruited into, and then were retained by the cages, dipnetted animals were sieved on the mesh of the cages—3 mm and 12 mm for the inner and outer cages, respectively. All retained animals were kept and identified to the lowest possible taxon.

To test for significant differences in mean abundance between pairs of samples, *t*-tests were used (Sokal and Rohlf, 1969).

RESULTS

TOTAL SAMPLES—There were 12,405 individuals collected, comprising 195 species, from all treatments combined. There were 9,491 individuals in 166 species collected from seagrass (Table 1) and 2,914 individuals in 127 species from sand (Table 2). Polychaetes were the most abundant and speciose group, although the gastropods *Bittium varium* and *Cylichnella canaliculata*[1] were top-ranked in seagrass and sand, respectively. The

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[1] *Cylichnella canaliculata* Say, 1826 had been recently placed in the genera *Acteocina* and *Utriculastra*, the latter a junior synonym of *Cylichnella* (see Gosliner, 1979).

TABLE 1. Seagrass species list and number of individuals of each species, all treatments combined (total sample area = 0.63 m^2). "Dominant" species had a mean of ≥ 2 individuals per treatment or ≥ 4 individuals from any 1 treatment and are ranked. Ties are indicated by t. "Non-dominant" species are unranked. (A = Amphipod, B = Bivalve, C = Crustacean, G = Gastropod, H = Holothurian, O = Ophiuroid, P = Polychaete, Ph = Phoronid, Pi = Pisces, S = Sipunculan, T = Tanaid.)

Rank	No. Indiv.	Dominant Species	Rank	No. Indiv.	Dominant Species
1	1298	*Bittium varium* (G)	45t	32	*Sayella crosseana* (G)
2	824	*Spiochaetopterus costarum oculatus* (P)	47	30	*Amygdalum papyrium* (B)
3	680	*Cymadusa compta* (A)	48	29	*Boonea impressa* (G)
4	647	Capitellidae (P)	49t	27	*Rissoina catesbyana* (G)
5	629	*Tharyx annulosus* (P)	49t	27	*Podarke obscura* (P)
6	482	*Crepidula convexa* (G)	49t	27	*Naineris setosa* (P)
7	376	*Ampithoe longimana* (A)	52	25	*Pagurus bonairensis* (C)
8	260	OLIGOCHAETA	53t	24	*Nassarius vibex* (G)
9	218	*Vitrinella floridana* (G)	53t	24	*Mercenaria mercenaria* (B)
10	212	*Astyris lunata* (G)	53t	24	*Mysella* sp. (B)
11	199	*Phascolion cryptus* (S)	56t	23	*Marphysa sanguinea* (P)
12t	177	*Branchioasychis americana* (P)	56t	23	*Typosyllis* spp. (P)
12t	177	*Cirriformia* sp. (P)	58	22	*Ophiophragmus filograneus* (O)
14	173	*Exogone* sp. (P)	59	20	*Schistomeringos rudolphi* (P)
15	168	*Caecum pulchellum* (G)	60	18	*Paracaprella tenuis* (A)
16	161	*Hippolyte pleuracanthus* (C)	61t	16	*Terebella rubra* (P)
17	158	*Erichsonella attenuata* (C)	61t	16	*Palaemonetes intermedius* (C)
18	156	*Diopatra cuprea* (P)	63	15	*Turbonilla incisa* (G)
19	126	*Hargeria rapax* (T)	64t	13	*Ampelisca vadorum* (A)
20	96	NEMERTINEA	64t	13	Syllidae (P)
21	90	*Parastarte triquetra* (B)	66t	12	*Scolelpis texana* (P)
22	89	*Gyptis brevipalpa* (P)	66t	12	TURBELLARIA
23	81	*Ampelisca abdita* (A)	66t	12	*Corophium ellisi* (A)
24	79	*Circulus suppressus* (G)	69t	11	*Gitanopsis tortugae* (A)
25t	75	*Glycinde solitaria* (P)	69t	11	*Crassostrea virginica* (B)
25t	75	*Fabricia sabella* (P)	69t	11	Sabellidae (P)
27	70	*Corophium* spp. (A)	72t	10	*Bopyrina abbreviata* (C)
28	68	*Turbonilla* sp. A (G)	72t	10	*"Odostomia" engonia* (G)
29	63	*Cylichnella canaliculata* (G)	72t	10	*Pista cristata* (P)
30	61	*Polydora ligni* (P)	75t	9	*Cirratulus* sp. (P)
31	57	*Axiothella mucosa* (P)	75t	9	*Parahesione luteola* (P)
32	56	*Crepidula plana* (G)	75t	9	*Scoloplos rubra* (P)
33	53	*Arichidea philbinae* (P)	75t	9	Terebellidae (P)
34t	52	*Grandidierella bonnieroides* (A)	79t	8	*Modulus modulus* (G)
34t	52	*Polydora socialis* (P)	79t	8	*Melita appendiculata* (A)
36	49	*Chone duneri* (P)	81t	7	*Melita elongata* (A)
37	45	*Erichthonius brasiliensis* (C)	81t	7	*Anadara transversa* (B)
38	44	*"Odostomia"* sp. B (G)	81t	7	PYCNOGONIDA
39	40	*Potamilla* sp. (P)	81t	7	Serpulidae (P)
40	36	*Chione cancellata* (B)	81t	7	*Onuphis simoni* (P)
41	35	*Haploscoloplos foliosus* (P)	81t	7	*Lysilla* sp. (P)
42t	34	*Pyrgocythara plicosa* (G)	87	6	*Synchelidium americanum* (A)
42t	34	*Cymodoce faxoni* (C)	88t	5	SIPUNCULA
42t	34	*Melinna maculata* (P)	88t	5	*Streblospio benedicti* (P)
45t	32	*Costoanachis avara* (G)	90	4	*Haploscoloplos* sp. (P)

TABLE 1. Continued.

No. Indiv.	Non-Dominant Species	No. Indiv.	Non-Dominant Species
10	*Prionospio heterobranchia* (P)	2	*Meioceras nitidum* (G)
10	*Lysidice ninetta ninetta* (P)	2	*Polycera hummi* (G)
9	Sabellaridae (P)	2	*Urosalpinx cinerea* (G)
8	"*Odostomia*" sp. A (G)	2	BIVALVIA, unidentifiable
7	*Haminoea antillarum* (G)	2	*Lucina pectinata* (B)
7	*Libinia* sp. (C)	2	*Lyonsia floridana* (B)
7	*Amphioplus thromboides* (O)	2	*Mysidopsis bigelowi* (C)
6	*Nereis succinea* (P)	2	*Thyonella gemmata* (H)
6	Hesionidae (P)	2	*Synaptula hydriformis* (H)
5	*Edotea montosa* (C)	2	*Phoronis* sp. (Ph)
5	OPHIUROIDEA (juv.)	1	*Arenicola cristata* (P)
4	*Glycera americana* (P)	1	*Pista quadrilobata* (P)
4	*Laeonereis culveri* (P)	1	*Sphaerosyllis glandulata* (P)
4	*Platynereis dumerilii* (P)	1	Polynoidae (P)
4	Pyramidellidae (G)	1	*Piromis roberti* (P)
4	*Musculus lateralis* (B)	1	*Amphitrite ornata* (P)
4	*Tellina tampaensis* (B)	1	*Lysidice ninetta collaris* (P)
4	*Oxyurostylis smithi* (C)	1	*Glycera* sp. (P)
4	*Neopanope packardi* (C)	1	Lumbrineridae (P)
4	*Gobiosoma robustum* (Pi)	1	*Ceratonereis mirabilis* (P)
3	*Capellinia conicla* (G)	1	Onuphidae (P)
3	*Ercolania fuscatus* (G)	1	*Haploscoloplos fragilis* (P)
3	*Abra aequalis* (B)	1	*Ancistrosyllis jonesi* (P)
3	*Macoma tenta* (B)	1	*Phyllodoce arenae* (P)
3	*Mulinia lateralis* (B)	1	*Branchiomma nigromaculata* (P)
3	*Sphenia antillensis* (B)	1	*Bulla striata* (G)
3	*Neopanope sayi* (C)	1	*Boonea seminuda* (G)
3	*Parapionosyllis longicirrata* (P)	1	*Fargoa gibbosa* (G)
3	HEMICHORDATA	1	*Haminoea succinea* (G)
3	PISCES	1	*Anomia simplex* (B)
2	Spionidae (P)	1	*Corbula contracta* (B)
2	*Sthenelais boa* (P)	1	*Nucula ?crenulata* (B)
2	*Polydora caulleryi* (P)	1	*Macoma brevifrons* (B)
2	Ampharetidae (P)	1	*Alpheus heterochaelis* (C)
2	Dorvilleidae (P)	1	*Myrophis* sp. (Pi)
2	Eunicidae (P)	1	ACTINARIA
2	Sigalionidae (P)	1	*Hippocampus zosterae* (Pi)
		1	undetermined

TABLE 2. Sand species list and number of individuals of each species, all treatments combined (total sample area = 0.63 m^2). "Dominant" species had a mean of ≥ 2 individuals per treatment of > 4 individuals from any one treatment and are ranked. Ties are indicated by t. "Non-dominant" species are unranked. (A = Amphipod, B = Bivalve, C = Crustacean, G = Gastropod, H = Holothurian, O = Ophiuroid, P = Polychaete, Ph = Phoronid, Pi = Pisces, S = Sipunculan, T = Tanaid.)

Rank	No. Indiv.	Dominant Species	Rank	No. Indiv.	Dominant Species
1	353	*Cylichnella canaliculata* (G)	5	198	*Spiochaetopterus costarum oculatus* (P)
2	277	Capitellidae (P)			
3	223	*Lysilla* sp. (P)	6	122	*Glycinde solitaria* (P)
4	221	*Axiothella mucosa* (P)	7	111	*Scolelepis texana* (P)

TABLE 2. Continued.

Rank	No. Indiv.	Dominant Species	Rank	No. Indiv.	Dominant Species
8	102	*Phascolion cryptus* (S)	29	19	*Nassarius vibex* (G)
9	87	*Oxyurostylis smithi* (C)	30t	18	*Synchelidium americanum* (A)
10	83	NEMERTINEA	30t	18	*Haploscoloplos foliosus* (P)
11	68	*Caecum pulchellum* (G)	32t	17	*Chione cancellata* (B)
12	63	*Branchioasychis americana* (P)	32t	17	TURBELLARIA
13	57	*Cirriformia* sp. (P)	34t	15	*Turbonilla* sp. (G)
14	56	*Polydora socialis* (P)	34t	15	*Ophiophragmus filograneus* (O)
15	55	*Parastarte triquetra* (B)	36t	14	*Ampelisca abdita* (A)
16	50	*Gyptis brevipalpa* (P)	36t	14	*Mercenaria mercenaria* (B)
17	36	HEMICHORDATA	36t	14	*Onuphis simoni* (P)
18	34	*Tharyx annulosus* (P)	39t	12	*Hargeria rapax* (T)
19	33	*Haploscoloplos fragilis* (P)	39t	12	*Crepidula convexa* (G)
20	31	OLIGOCHAETA	39t	12	*Erichthonius brasiliensis* (A)
21	30	*Cirratulus* sp. (P)	42	10	*Synaptula hydriformis* (H)
22	28	*Bittium varium* (G)	43	8	*Haminoea antillarum* (G)
23	27	*Phoronis psammophila* (Ph)	44t	7	*Astyris lunata* (G)
24t	22	*Cymadusa compta* (A)	44t	7	*Modulus modulus* (G)
24t	22	*Diopatra cuprea* (P)	44t	7	Cirratulidae (P)
26	21	*Aricidea philbinae* (P)	44t	7	*Corophium ellisi* (A)
27t	20	Kalliapseudidae (T)	48	5	*Bowmaniella dissimilis* (C)
27t	20	*Turbonilla incisa* (G)			

No. Indiv.	Non-Dominant Species	No. Indiv.	Dominant Species
10	*Cabira incerta* (P)	3	*Abra aequalis* (B)
10	*Mysidopsis bigelowi* (C)	3	*Erichsonella attenuata* (C)
8	*Ampithoe longimana* (A)	3	*Cymodoce faxoni* (C)
8	*Marphysa sanguinea* (P)	3	*Hippolyte pleuracanthus* (C)
7	*Polydora obscura* (P)	3	*Penaeus duorarum* (C)
7	*Polydora ligni* (P)	2	*Pagurus bonairensis* (C)
6	*Lyonsia floridana* (B)	2	*Gitanopsis tortugae* (A)
6	*Mulinia lateralis* (B)	2	*Lysidice ninetta ninetta* (P)
6	*Tellina tampaensis* (B)	2	*Phyllodoce arenae* (P)
6	*Ptilanthura tricarina* (C)	2	*Chone duneri* (P)
5	*Listriella barnardi* (A)	2	*Schistomeringos rudolphi* (P)
5	*Scoloplos rubra* (P)	2	*Terebella rubra* (P)
5	*Crepidula plana* (G)	2	*Eteone heteropoda* (P)
5	*Tagelus plebeius* (B)	2	*Malacoceras vanderhorsti* (P)
5	*Tellina mera* (B)	2	*Myrophis* sp. (Pi)
4	*Prionospio heterobranchia* (P)	2	*Amygdalum papyrium* (B)
4	*Exogone* sp. (P)	2	*Anomalocardia auberiana* (B)
4	Terebellidae (P)	2	*Ampelisca vadorum* (A)
4	*Bulla striata* (G)	2	*Sphenia antillensis* (B)
4	*Pyrgocythara plicosa* (G)	2	BIVALVIA, undet.
4	*Apanthura magnifica* (C)	2	*Cerapus tubularis* (A)
3	Lumbrineridae (P)	2	*Paracaprella tenuis* (A)
3	*Platynereis dumerilii* (P)	1	*Grandidierella bonnieroides* (A)
3	*Nereis succinea* (P)	1	*Typosyllis annularis* (P)
3	*Haminoea succinea* (G)	1	*Parapionosyllis longicirrata* (P)

Table 2. Continued.

No. Indiv.	Dominant Species	No. Indiv.	Dominant Species
1	*"Odostomia"* sp. B (G)	1	Thalassinoidea (C)
1	*Prunum apicinum* (G)	1	*Thyonella gemmata* (H)
1	Pyramidellidae, undet. (G)	1	Caprellidae (A)
1	*Smaragdia viridis viridemaris* (G)	1	Mysidae (C)
		1	*Glycera americana* (P)
1	*Vitrinella floridana* (G)	1	*Laeonereis culveri* (P)
1	*Mysella* sp. (B)	1	*Eteone* sp. (P)
1	*Tellina versicolor* (B)	1	Sabellidae (P)
1	*Tellina* sp. (B)	1	*Prionospio* sp. (P)
1	*Tagelus divisus* (B)	1	Sigalionidae (P)
1	*Edotea montosa* (C)	1	*Sthenelais boa* (P)
1	*Bopyrina abbreviata* (C)	1	*Armandia* sp. (P)
1	*Lysianassa alba* (C)	1	*"Odostomia" engonia* (G)
1	*Callinectes ornatus* (C)	1	*"Odostomia"* sp. A (G)
1	*Upogebia* sp. (C)		

polychaete fraction comprised 5,365 individuals in 75 species, 43% and 39% of the total individuals and species, respectively. *Spiochaetopterus costarum oculatus* and Capitellidae ranked among the top 5 dominants in both habitats. Mollusks made up 34% of total individuals in seagrass and only 24% in sand. Crustacean density exhibited a large seagrass-sand difference, comprising over 20% of total individuals (3,071/m^2) in seagrass and only 9% (414/m^2) in sand—7.4 times as dense in seagrass.

The Natural Communities—A comparison of total samples from natural (uncaged) seagrass (Table 3) and sand (Table 4) habitats shows both similarities and differences (Table 5). Mean density of total macrofauna in seagrass (17,479/m^2) was 3 times the mean density in sand (5,844/m^2). There were also 40% more species taken from seagrass (135) than from sand (97), even though informational diversity indices (H′) were very similar (Table 5). Overlap of species composition was high: the top 23 species (and 37 of the top 38) in seagrass also occurred in sand, and the top 35 species in sand also occurred in seagrass. Gastropods were the top-ranked numerical dominant in both habitats—the epifaunal *Bittium varium* in seagrass and the infaunal *Cylichnella canaliculata* in sand (Tables 3, 4).

Although species compositions of the 2 habitats were similar, there were large differences in abundance. For example, although crustaceans comprised only 17% of the number of species taken from seagrass versus 27% from sand, they constituted 18% (3,151/m^2) of total individuals in seagrass versus only 8% (480/m^2) in sand. Polychaetes made up similar proportions of species in seagrass (43% of total) and sand (35%). However, polychaetes comprised a much smaller proportion of total individuals in seagrass (36%) than in sand (58%). Gastropods comprised 19% of the total number of

TABLE 3. Seagrass dominants from uncaged control samples: their percent of total N (4,711 individuals, from a total sample area of 0.27 m²), and the ratio of seagrass density to sand density in controls. (A = Amphipod, B = Bivalve, D = Decapod, G = Gastropod, I = Isopod, P = Polychaete, S = Sipunculan, T = Tanaid; e = epifaunal, i = infaunal). Ties are indicated by t.

Rank	%	Species	Grass: Sand	Rank	%	Species	Grass: Sand
1	18.40	*Bittium varium* (G,e)	108.0	23	0.91	*Polydora socialis* (P,i)	0.9
2	9.09	*Spiochaetopterus costarum oculatus* (P,i)	4.7	24	0.89	*Corophium* spp. (A,i)	∞
3	7.60	*Cymadusa compta* (A,e)	89.5	25t	0.85	*Axiothella mucosa* (P,i)	0.3
4	6.05	Capitellidae (P,i)	1.9	25t	0.85	*Exogone* sp. (P,i)	20.0
5	4.35	*Crepidula convexa* (G,e)	29.0	25t	0.85	*Turbonilla* sp. (G,i)	10.0
6	3.88	*Ampithoe longimana* (A,e)	45.8	28	0.81	*Hippolyte pleuracanthus* (D,e)	19.0
7	3.80	*Tharyx annulosus* (P,i)	8.1	29	0.79	*Hargeria rapax* (T,e)	7.4
8	2.93	*Phascolion cryptus* (S,i)	2.7	30	0.62	*Crepidula plana* (G,e)	5.8
9	2.59	*Astyris lunata* (G,e)	61.0	31	0.59	*Grandidierella bonnieroides* (A,e)	14.0
10	2.55	*Branchioasychis americana* (P,i)	4.1	32	0.49	*"Odostomia"* sp. B (G,e)	∞
11	2.19	OLIGOCHAETA (i)	7.3	33	0.45	*Ampelisca abdita* (A,i)	3.5
12	1.83	*Erichsonella attenuata* (I,e)	∞	34	0.42	*Pyrgocythara plicosa* (G,e)	10.0
13	1.70	*Vitrinella floridana* (G,e)	∞	35	0.40	*Rissoina catesbyana* (G,e)	∞
14	1.68	*Diopatra cuprea*(P,i)	8.0	36	0.34	*Sayella crosseana* (G,i)	∞
15	1.46	*Circulus suppressus* (G,e)	∞	37t	0.28	*Costoanachis avara* (G,e)	∞
16	1.36	*Caecum pulchellum* (G,i)	1.7	37t	0.28	*Amygdalum papyrium* (B,e)	13.0
17	1.33	*Cirriformia* sp. (P,i)	2.5	37t	0.28	*Paracaprella tenuis* (A,e)	6.5
18	1.29	*Parastarte triquetra* (B,i)	3.2	40t	0.23	*Pagurus bonairensis* (D,e)	∞
19	1.17	*Cylichnella canaliculata* (G,i)	0.2	40t	0.23	*Turbonilla incisa* (G,i)	0.8
20	1.15	NEMERTINEA (i)	1.7	40t	0.23	*Boonea impressa* (G,e)	∞
21	1.02	*Glycinde solitaria* (P,i)	0.8	43	0.21	TURBELLARIA (i)	0.8
22	0.93	*Erichthonius brasiliensis* (A,e)	3.4	44t	0.19	*Cymodoce faxoni* (I,e)	4.5
				44t	0.19	*Nassarius vibex* (G,e)	0.8

species in both seagrass and sand. Unlike the polychaetes, however, gastropods were most abundant in seagrass, comprising 36% (6,200/m²) of total individuals in seagrass, versus only 21% (1,230/m²) in sand (35% of total individuals in seagrass and only 7% in sand, excluding *Cylichnella canaliculata*, which was dominant in sand).

Epifaunal abundance showed the greatest difference between the 2 communities, being 13 times greater in seagrass than in sand. Epifauna in seagrass comprised 4 of the top 6 species and 22 of the top 45, whereas in the sand there were no epifaunal species in the top 22 and only 9 in the top 45 species. In seagrass, epifauna comprised 54% (9,248/m²) of total individuals versus only 12% (722/m²) in sand. Epifaunal amphipods, particularly *Cymadusa compta* and *Ampithoe longimana* were more abundant in seagrass (14% of individuals, 2,345/m²) than in sand (2% of individuals, 93/m²), even though there were as many species (8) in sand as in seagrass. Epifaunal gastropods also were more abundant in seagrass (3 of the top 10 species, 33% of total individuals, 5,648/m²) than in sand (none of the top 22 species, 6% of total individuals, 333/m²).

Total crustaceans also were more abundant in seagrass (18% of total individuals, 3,152/m²) than in sand (8% of total individuals, 485/m²), even though there were more species of crustaceans in sand (26 vs. 23). Although not numerically dominant, decapod crustaceans were more abundant in seagrass (215/m²) than in sand (15/m²).

TABLE 4. Sand dominants from uncaged control samples: their percent of total N (1,578 individuals, from a total of 0.27m²), and the ratio of sand density to seagrass density in controls. (A = Amphipod, B = Bivalve, G = Gastropod, M = Mysid, O = Ophiuroid, P = Polychaete, S = Sipunculan, T = Tanaid; e = epifaunal, i = infaunal.)

Rank	%	Species	Sand: Grass	Rank	%	Species	Sand: Grass
1	14.23	*Cylichnella canaliculata* (G,i)	4.1	23t	0.76	*Synchelidium americanum* (A,i)	2.0
2	11.28	*Lysilla* sp. (P,i)	44.5	25t	0.70	*Erichthonius brasiliensis* (A,e)	0.3
3	9.82	Capitellidae (P,i)	0.5	25t	0.70	*Aricidea philbinae* (P,i)	0.5
4	7.67	*Axiothella mucosa* (P,i)	3.0	27	0.63	*Diopatra cuprea* (P,i)	0.1
5	5.77	*Spiochaetopterus costarum oculatus* (P,i)	0.2	28t	0.57	Kalliapseudidae (T,i)	∞
6t	3.68	*Glycinde solitaria* (P,i)	1.2	28t	0.57	*Phoronis psammophila* (Ph,i)	4.5
6t	3.68	*Scolelepis texana* (P,i)	8.2	28t	0.57	*Ophiophragmus filograneus* (O,i)	1.3
8	3.23	*Phascolion cryptus* (S,i)	0.4	31	0.51	*Bittium varium* (G,e)	0.01
9	3.17	*Polydora socialis* (P,i)	1.2	32t	0.44	*Corophium ellisi* (A,i)	∞
10	2.53	*Oxyurostylis smithi* (C,i)	20.0	32t	0.44	*Modulus modulus* (G,e)	7.0
11	2.34	*Caecum pulchellum* (G,e)	0.6	32t	0.44	*Crepidula convexa* (G,e)	0.03
12t	2.03	*Haploscoloplos fragilis* (P,i)	32.0	35	0.38	*Mysidopsis bigelowi* (M,i)	6.0
12t	2.03	NEMERTINEA (i)	0.6	36t	0.32	*Listriella barnardi* (A,i)	∞
14	1.96	*Gyptis brevipalpa* (P,i)	0.8	36t	0.32	*Hargeria rapax* (T,e)	0.1
15	1.84	*Branchioasychis americana* (P,i)	0.2	36t	0.32	*Bowmaniella dissimilis* (M,i)	∞
16	1.52	HEMICHORDATA (i)	24.0	39	0.31	*Crepidula plana* (G,e)	0.2
17	1.40	*Tharyx annulosus* (P,i)	0.1	40t	0.25	*Turbonilla* sp. (G,i)	0.1
18	1.33	*Cirriformia* sp. (P,i)	0.4	40t	0.25	*Cymadusa compta* (A,e)	0.01
19	1.20	*Parastarte triquetra* (B,i)	0.3	40t	0.25	*Ampelisca abdita* (A,i)	0.2
20	0.89	OLIGOCHAETA (i)	0.1	43t	0.19	*Chione cancellata* (B,i)	0.4
21t	0.82	TURBELLARIA (i)	1.3	43t	0.19	*Bulla striata* (G,e)	∞
21t	0.82	*Turbonilla incisa* (G,i)	1.2	43t	0.19	*Tellina tampaensis* (B,i)	1.0
23t	0.76	*Nassarius vibex* (G,e)	1.3				

In sand, infaunal polychaetes dominated. Six of the top 7, and 12 of the top 18 species were infaunal polychaetes, the total of which comprised 58% of total individuals versus only 36% in seagrass.

Species especially more abundant in seagrass than in sand (density ratio >4, and >1% occurrence; Table 3) include *Bittium varium*, *Cymadusa compta*, *Astyris lunata*, *Ampithoe longimana*, *Vitrinella floridana*, *Erich-*

TABLE 5. Seagrass-sand comparisons, based on control samples: A) Density and diversity (H′ = diversity, d = richness, J′ = evenness); B) Dominance—as percent of total individuals (N); C) Contribution of various taxa—as percent of N; and as frequency of occurrence of species; D) Epifauna versus infauna—as percent of N; and frequency of occurrence.

A. Density and diversity		
	Seagrass	*Sand*
	17,479 m^2	5,844/m^2
	92.7 spp./sample	63.7 spp./sample
	134 spp. total	97 spp. total
	$H' = 4.76$	$H' = 4.56$
	$d = 12.49$	$d = 10.05$
	$J' = 0.73$	$J' = 0.76$
B. Dominance	*Seagrass*	*Sand*
	Top sp. = 18%	Top sp. = 14%
	Top 10 spp. = 61%	Top 10 spp. = 64%
	Top 46 spp. = 90%	Top 37 spp. = 90%
C. Contribution of major taxa		
Taxon	*Seagrass*	*Sand*
Polychaeta	36% of N	58% of N
	4 of top 13 spp.	6 of top 7 spp.
Mollusca	36% of N	21% of N
Gastropoda	7 of top 19 spp.	2 of top 20 spp.
Crustacea	18% of N	8% of N
Amphipoda	2 of top 6 spp.	None in top 22 spp.
	2,482/m^2	133/m^2
Decapoda	1.3% of N	0.3% of N
	215/m^2	15/m^2
D. Epifauna versus infauna		
	Seagrass	*Sand*
Epifauna	54% of N	12% of N
	4 of top 6 spp.	None in top 22 spp.
	22 of top 45 spp.	9 of top 45 spp.
Infauna	46% of N	88% of N
	2 of top 6 spp.	All of top 21 spp.

sonella attenuata, *Circulus suppressus*, *Tharyx annulosus*, *Crepidula convexa*, *Diopatra cuprea*, *Spiochaetopterus costarum oculatus*, *Branchioasychis americana* and Oligochaeta—13 of the top 15 species in seagrass.

Species more abundant in sand (Table 4) than in seagrass (density ratio >3, and >1% occurrence) include *Lysilla* sp., *Haploscoloplos fragilis*, *Cylichnella canaliculata*, *Oxyurostylis smithi*, Hemichordata, *Scolelepis texana* and *Axiothella mucosa*.

Species abundant in both seagrass and sand habitats (>1% of individuals) include *Cylichnella canaliculata*, *Spiochaetopterus costarum oculatus*, Capitellidae, *Tharyx annulosus*, *Phascolion cryptus*, *Branchioasychis americana*, *Cirriformia* sp. and *Parastarte triquetra*—7 of the top 16 species overall.

CAGING—Abundance of total individuals in both seagrass and sand followed the same 2 trends: 1) outer cage density most closely approximated

TABLE 6. Dominant seagrass species and their response to caging. A comparison of number of individuals per 1/11 m^2 in uncaged control and inner cage samples taken on 27 June 1978, after cages had been in place 2 mo. Dominant species (Table 3) with ≥ 6 individuals in any 1 of the treatments are listed. Asterisks (*) indicate significantly greater abundance ($p < .05$). (A = Amphipod, B = Bivalve, D = Decapod, G = Gastropod, I = Isopod, P = Polychaete, S = Sipunculan, T = Tanaid; e = epifaunal, i = infaunal.) Ties are indicated by t.

Rank	Species (Type, habit)	No. Individuals per 1/11 m^2 Control	Cage	Cage:Control
7	*Tharyx annulosus* (P,i)	11	96	8.7
29	*Hargeria rapax* (T,e)	5	30	6.0
28	*Hippolyte pleuracanthus* (D,e)	5	26	5.2
5	*Crepidula convexa* (G,e)	41	71	1.7
10	*Branchioasychis americana* (P,i)	13	18	1.4
25t	*Exogone* sp. (P,i)	28	38	1.4
6	*Ampithoe longimana* (A,e)	26	32	1.2
11	OLIGOCHAETA (i)	16	19	1.2
17	*Cirriformia* sp. (P,i)	27	27	1.0
2	*Spiochaetopterus costarum oculatus* (P,i)	89	85	0.95
14	*Diopatra cuprea* (P,i)	23	20	0.87
16	*Caecum pulchellum* (G,e)	11	9	0.82
32	"*Odostomia*" sp. B (G,i)	10	8	0.80
4	Capitellidae (P,i)	73	58	0.79
13	*Vitrinella floridana* (G,i)	54	40	0.74
31	*Grandidierella bonnieroides* (A,e)	15	11	0.73
30	*Crepidula plana* (G,e)	8	5	0.63
3	*Cymadusa compta* (A,e)	139	84	0.60
44t	*Nassarius vibex* (G,e)	7	4	0.57
20	NEMERTINEA (i)	16	9	0.56
18	*Parastarte triquetra* (B,i)	9	4	0.44
37t	*Costoanachis avara* (G,e)	9	3	0.33
34	*Pyrgocythara plicosa* (G,e)	13	4	0.31
8	*Phascolion cryptus* (S,i)	37*	11	0.30
35	*Rissoina catesbyana* (G,e)	18	5	0.28
25t	*Turbonilla* sp. (G,i)	35	8	0.23
24	*Corophium* spp. (A,e)	19	4	0.21
9	*Astyris lunata* (G,e)	35	6	0.17
40t	*Pagurus bonairensis* (D,e)	7	1	0.14
12	*Erichsonella attenuata* (I,e)	26*	3	0.12
1	*Bittium varium* (G,e)	545*	47	0.09
19	*Cylichnella canaliculata* (G,i)	7*	0	0
15	*Circulus suppressus* (G,e)	69	0	0
--	Total DECAPODA	14	30	2.1
--	Total individuals	1647*	924	0.56
--	No. spp./core	53.5	44.8	0.84

control density, and 2) inner cage density was higher than other treatments at the end of the first month (April to May), but then declined sharply during the second month (May to June), becoming the lowest density of any treatment at any time (Fig. 1). In June the control density was 1.8 times inner cage density in the seagrass (Table 6) and 2.9 times inner cage density in the sand (Table 7). The 44% increase in seagrass control density from May to June (Fig. 1) was due primarily to the natural recruitment period of

Bittium varium, which increased in density in controls from 2,431 to 6,050/m^2.

Individual species responses to caging are summarized by comparing final (June) inner cage and control densities (Tables 6, 7). Detailed patterns of response for individual species are not presented for the following reasons: 1) most species followed the same 2 trends (given above) as total density, 2) differences after 1 mo were less than after 2 mo, and 3) density in the outer cages was intermediate to control and inner cage densities, although closer to control density.

After 2 mo, few species had increased in density within the inner cages: only 9 of the top 33 dominant species in seagrass, and 3 of 21 in sand. In seagrass, there were no species significantly more abundant in the inner cages than in their controls (t-test, $p < .05$). Four species were significantly less abundant in the inner seagrass cages than in their controls: *Cylichnella canaliculata*, *Bittium varium*, *Erichsonella attenuata*, and *Phascolion cryptus*, along with total individuals (Table 6). In sand, no species had significantly higher density in the inner cages than in controls, while 2 species of polychaetes had significantly lower densities: *Axiothella mucosa* and *Glycinde solitaria* (Table 7).

The only group of animals consistently more abundant in the inner cages than in controls or outer cages was the decapod crustaceans (Fig. 2). Their density within the inner cages increased during the first month, then declined during the second, while densities within the outer cages were consistently similar to densities of the controls.

Although most of the decapods collected with the corer and retained by the small (0.5 mm) mesh were small hippolytid shrimp, the decapods dipnetted from the cages after the final core sampling consisted of larger animals retained by the 3-mm or 12-mm mesh of the cages—primarily of the families Palaemonidae, Paguridae, Alpheidae, Penaeidae and Xanthidae, as well as Hippolytidae (Table 8). The mean density of these larger decapods (80/m^2) plus fishes (14/m^2) in the inner seagrass cages was an abnormally high concentration of predators (Fig. 3A). To a lesser degree, this was true also in the sand (Fig. 3B).

DISCUSSION

Natural Seagrass versus Sand—The large differences demonstrated between seagrass and sand fauna were primarily differences in abundance, rather than in species composition. The main difference to be emphasized here is the higher density in seagrass: epifauna were 13 times more abundant and crustaceans 7 times more abundant than in sand. In light of the increased habitat, food, and protection from predators provided by seagrass, this greater abundance in seagrass is not surprising. O'Gower and Wacasey

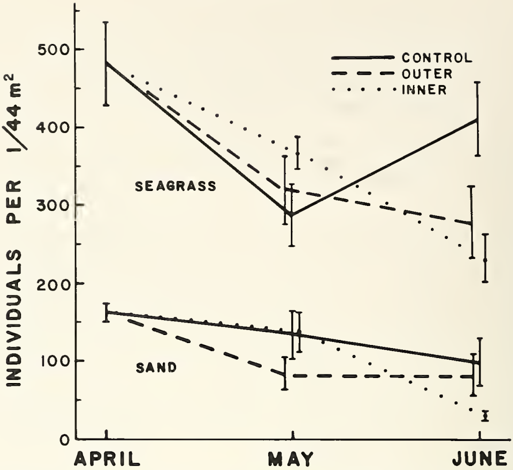

FIG. 1. Density of total individuals in uncaged control and in inner (3-mm mesh) and outer (12-mm mesh) cages. Means ± $s_{\bar{x}}$.

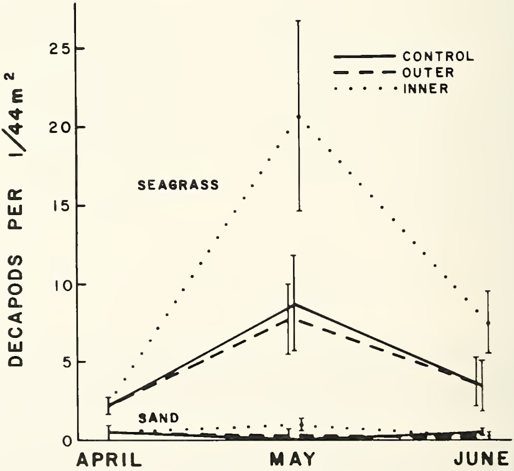

FIG. 2. Density of decapod crustaceans in uncaged control and in inner (3-mm mesh) and outer (12-mm mesh) cages. Means ± $s_{\bar{x}}$.

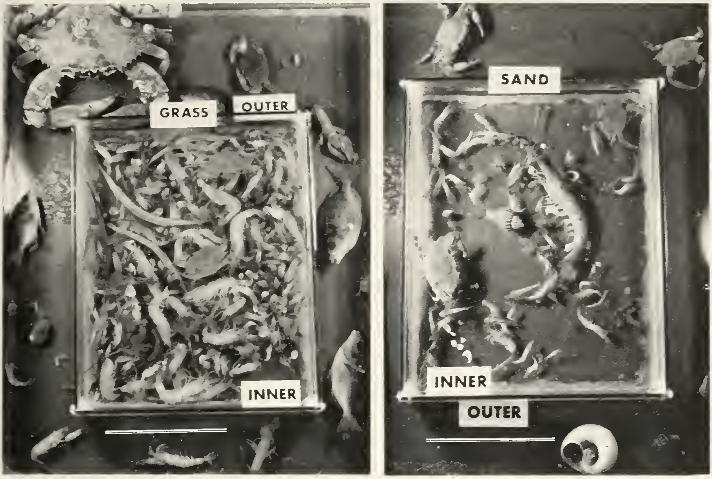

FIG. 3. Photograph of the animals dipnetted in June from 1 inner and outer cage and retained by the 3-mm and 12-mm mesh, respectively in A) seagrass cage and B) sand cage. Scale bar = 10 cm.

(1967), Kikuchi (1974), Santos and Simon (1974), Orth (1977) and Virnstein (1978) all reported higher densities of macrobenthos in seagrass than in adjacent bare sand (Table 9).

Taken alone, higher macrofaunal densities do not necessarily demonstrate greater trophic importance, defined here as "direct contribution to the food web." In addition to the greater density of macrobenthos (especially epifauna) in seagrass, the densities of their predators — the decapods and fishes — are greater also (Briggs and O'Connor, 1971; Heck and Orth, 1980; Orth and Heck, 1980; Table 9). At the same site and time period as in the present study, using 10-m^2 drop nets, R.G. Gilmore (Harbor Branch Foundation, unpublished) found mean fish density in the seagrass (6/m^2) to be 9 times the density over adjacent bare sand. Thus, based on higher densities in seagrass of both macrobenthos and their predators, the macrobenthos of seagrass appear to be tropically more important.

Although the above conclusions may apply in general to broad geographic areas, details may be very site-specific—as seen by comparison with a nearby seagrass area. Within a week of each of the 3 sampling dates of the present study, samples were taken in an identical manner from a *Halodule wrightii* seagrass bed at our long-term Link Port, site 2.1 km south of the present study. In the same number of samples at both sites, there were 3,258 *Modulus modulus* and 3,051 *Cerithium muscarum* taken at the Link

TABLE 7. Dominant sand species and their response to caging. A comparison of number of individuals per 1/11 m^2 in uncaged control and inner cage samples taken on 27 June 1978, after cages had been in place 2 mo. Dominant species (Table 4) with ≥ 4 individuals in any 1 of the treatments are listed. Asterisks (*) indicate significantly greater abundance ($p<.05$). (B = Bivalve, G = Gastropod, M = Mysid, P = Polychaete, S = Sipunculan; e = epifaunal, i = infaunal.) Ties are indicated by t.

		No. Individuals per 1/11 m^2		
Rank	Species (Type, habit)	Control	Cage	Cage:Control
20	OLIGOCHAETA (i)	1	5	5.0
18	*Cirriformia* sp. (P,i)	9	12	1.3
31	*Bittium varium* (G,e)	7	7	1.0
5	*Spiochaetopterus costarum oculatus* (P,i)	19	18	0.95
32t	*Crepidula convexa* (G,e)	4	3	0.75
12t	NEMERTINEA (i)	15	11	0.73
15	*Branchioasychis americana* (P,i)	17	10	0.59
14	*Gyptis brevipalpa* (P,i)	4	2	0.50
8	*Phascolion cryptis* (S,i)	27	13	0.48
23t	*Nassarius vibex* (G,e)	5	2	0.40
19	*Parastarte triquetra* (B,i)	8	3	0.38
3	Capitellidae (P,i)	25	7	0.28
6t	*Glycinde solitaria* (P,i)	15*	3	0.20
2	*Lysilla* sp. (P,i)	11	2	0.18
6t	*Scolelepis texana* (P,i)	7	1	0.14
36t	*Bowmaniella dissimilis* (M,e)	4	0	0
21t	TURBELLARIA (i)	5	0	0
17	*Tharyx annulosus* (P,i)	7	0	0
11	*Caecum pulchellum* (G,e)	23	0	0
4	*Axiothella mucosa* (P,i)	23*	0	0
1	*Cylichnella canaliculata* (G,i)	92	0	0
--	Total DECAPODA	2	1	0.50
--	Total individuals	391	133	0.34
--	No. spp./core	28.8*	16.8	0.58

Port site, but only 1 and none, respectively, of these epifaunal gastropods were taken at the present study site. Both species undergo direct development in the Indian River (Houbrick, 1973, 1980; pers. obser.), which could contribute to the maintenance of such localized populations.

CAGING—The "failure" to produce the originally-expected density decrease in the outer cages and increase in the inner cages is now explainable. The decrease in density within the inner cages during the May-to-June period (Fig. 1) is attributed to predation on the macrobenthos by the high density of decapods and fishes (Fig. 3, Table 8). Even though decapod density decreased during this second month (Fig. 2), an increase in size of those decapods present could have resulted in increased predation intensity on the macrobenthos. By excluding larger fish which prey on decapods (Carr and Adams, 1973; Adams, 1976), a few of the decapods (e.g., *Callinectes* spp.) subsequently could have grown large enough to prey on other decapods.

TABLE 8. Numbers of decapods and fishes per 4 m² dipnetted from inner and outer cages after final macrobenthos sampling in June and retained by mesh of inner (3-mm mesh) or outer (12-mm mesh) cages.

Species	*Seagrass* Inner	*Seagrass* Outer	*Sand* Inner	*Sand* Outer
Decapoda				
Alpheus heterochaelis	50	3	1	1
Alpheus normanni	4	-	-	-
Hippolyte pleuracanthus	14	-	-	-
Palaemonetes intermedius	122	-	17	-
Penaeus duorarum	31	4	24	-
Pagurus bonairensis	65	-	-	-
Clibanarius vittatus	-	-	-	2
Callinectes ornatus	7	6	3	7
Neopanope sayi	13	-	-	1
Neopanope packardii	8	-	-	-
Libinia dubia	4	5	-	-
Total Decapods	318	18	46	11
Pisces				
Gobiosoma robustum	38	-	16	-
Lagodon rhomboides	1	6	-	2
Strongylura notata	9	-	-	-
Syngnathus scovelli	5	-	-	-
Chasmodes saburrae	1	-	-	-
Total Fishes	54	6	16	2

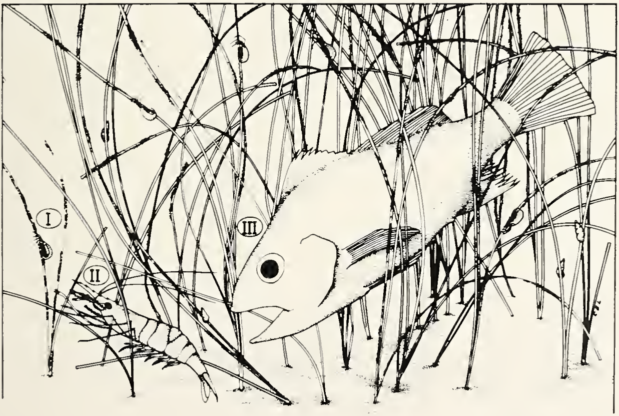

FIG. 4. A proposed major food web for Indian River seagrass beds. Depicted is (I) the grazing epifaunal amphipod *Cymadusa compta* about to be preyed upon by (II) *Palaemonetes intermedius* which is about to be preyed upon by (III) *Bairdiella chrysura*. Other genera probably important include (non-exclusively): trophic level I: *Bittium*, *Ampithoe*, *Grandidierella*, *Corophium* and *Hippolyte*; level II: *Penaeus*, *Alpheus*, *Gobiosoma*, *Syngnathus* and *Eucinostomus*; level III: *Cynoscion*, *Lutjanus*, *Orthopristis* and *Haemulon*. Important genera that may span trophic levels (depending on size) include: *Palaemonetes* (levels I and II), and *Callinectes* and *Lagodon* (levels II and III).

TABLE 9. Comparison of seagrass: sand faunal density ratio with other studies. Abundances are per m^2 except those listed in parentheses. Faunal groups: M = macrobenthos, P = polychaetes, Cr = crustaceans, De = decapods, F = fishes, Mo = mollusks. Collection gear: Co = corer, Dr = dropnet, Sl = sledge, Tr = trawl, Se = seine. References: PS = present study, G = Gilmore (unpub.), V = Virnstein (1978), O = Orth (1977), SS = Santos and Simon (1974), OW = O'Gower and Wacassey (1967), YY = Young and Young (1982), K = Kikuchi (1974), HO = Heck and Orth (1980), OH = Orth and Heck (1980), BO = Briggs and O'Connor (1971).

Area	Seagrass	Faunal Group	Coll. Gear	Sieve mesh (mm)	Abundance Grass (G)	Sand (S)	G:S Ratio	Source
Indian River, FL	*Thalassia/Halodule*	M	Co	0.5	17,479	5,844	3.0	PS
Indian River, FL	"	P	Co	0.5	6,248	3,403	1.8	PS
Indian River, FL	"	Cr	Co	0.5	3,152	485	6.5	PS
Indian River, FL	"	De	Co	0.5	215	15	14.3	PS
Indian River, FL	"	F	Dr	3.2	6.1	0.7	8.8	G (unpub.)
Indian River, FL	*Halodule*	M	Co	1.0	7,460	2,530	2.9	V (1978)
Chesapeake Bay, VA	*Zostera*	M	Co	0.5	39,000	7,850	5.0	V (1978)
Chesapeake Bay, VA	*Zostera*	M	Co	1.0	48,900	1,160	42.2	O (1977)
Tampa Bay, FL	*Halodule*	P	Co	0.5	13,313	8,462	1.6	SS (1974)
"	*Thalassia*	P	Co	0.5	33,485	"	4.0	SS (1974)
Biscayne Bay, FL	*Halodule*	M	Co	1.0	(1,245)	(774)	1.6	OW (1967)
"	*Thalassia*	M	Co	1.0	(771)	"	1.0	OW (1967)
Carrie Bow, BELIZE	*Thalassia*	Mo + P	Co	1.0	6,476	8,000	0.8	YY (1982)
Seto Sea, JAPAN	*Zostera*	M	Sl	--	(2,755)	(824)	3.3	K (1974)
"	"	Cr	Sl	--	(2,054)	(435)	4.7	K (1974)
Chesapeake Bay, VA	*Zostera*	De	Tr	--	(17,292)	(927)	18.7	HO (1980)
Chesapeake Bay, VA	*Zostera*	F	Tr	--	(1,090)	(164)	6.7	OH (1980)
Long Is. Sound, NY	*Zostera*	F	Se	--	(337,677)	(139,264)	2.4	BO (1971)

In lab and field experiments following the present study, Nelson (1981a) has shown that 2 species of shrimp abundant in the inner cages, *Palaemonetes intermedius* and *Penaeus duorarum*, can "exert strongly negative effects on the density of macrobenthos associated with seagrasses in the Indian River." In experiments utilizing *Callinectes sapidus* (blue crab) and *Lagodon rhomboides* (pinfish) as predators, Nelson (1981a) found that they had less effect than the shrimps on most other species of macrobenthos, probably because the large individuals of both species (95-140 mm) utilized in the experiments preyed on smaller decapods which are themselves predators on other macrobenthos. Although smaller pinfish (16-60 mm) are effective predators on amphipods, large pinfish (> 120 mm) are largely herbivorous (Stoner, 1979, 1980; Livingston, 1982; studies done in Apalachee Bay, FL). In eelgrass beds in Australia, predation by shrimps has a larger impact on small epifaunal species than does predation by fishes (Howard, 1983; Robertson, 1983).

Taken together, the evidence indicates that predation by decapods and fishes is an important factor regulating densities of macrobenthos, especially the epifauna (as suggested by Nelson et al., 1982). A proposed major food web in Indian River seagrasses is thus: grazing epifauna are preyed upon by small decapods which are in turn preyed upon by fishes (Fig. 4) and perhaps large decapods. Such a food web involving primarily the epifauna is nearly absent in sand habitats—a major trophic difference between the two communities. Based on the magnitude of the prey response to caging, the sand infauna is preyed upon, but cannot support as many predators as the seagrass epifauna. Within seagrass meadows, the epifauna are more heavily preyed upon than seagrass infauna (Nelson, 1979).

PROBLEMS ENCOUNTERED—The problems encountered in the course of this caging study and others (Virnstein, 1978) should serve as a caveat to other researchers. In spite of the small (3 mm) mesh used for the inner cages and the diligence with which predators were removed from these cages, decapod crustaceans recruited through the mesh in high numbers. In the follow-up experiments by Nelson (1981a,b), decapods recruited through even finer mesh (1.2 mm) in an even shorter time period (3 wk); decapods seem to recruit as fast as other macrofauna. Structures such as cages act as refuges and "attract" mobile fauna such as decapods and fishes (Virnstein, 1978); other researchers have had this same problem (Woodin, 1974; Young et al., 1976; Young and Young, 1977, 1978; Arntz, 1977; Reise, 1977, 1978). We conclude that it is nearly impossible to exclude small decapod crustacean predators from local seagrass beds for all but a very short time—perhaps a week. Thus it seems likely that the experiments of Young et al. (1976) and Young and Young (1977, 1978) were not appropriate for answering questions about the role of predation on macrobenthos. If the aim is to exclude small decapods from an area, using large-mesh cages to enclose a predator on these decapods may be more successful than trying to exclude small decapods with small-mesh cages. In our local situation, such a decapod predator might be the silver perch, *Bairdiella chrysura*, or the spotted seatrout, *Cynoscion nebulosus* (Darnell, 1958; Tabb, 1961; Carr and Adams, 1973; Adams, 1976; Livingston, 1982; R.G. Gilmore, pers. comm.). The alternative of attempting the experiment in a season when decapods are not recruiting is not viable locally, because many of the species recruit virtually throughout the year (R.H. Gore, pers. comm.).

CONCLUSIONS—In summary, not only are densities of macrofauna much greater in seagrass than in sand, but those animals which are more abundant in seagrass (the epifauna especially) are also more heavily preyed on, and thus are trophically more important than the infauna of seagrass. The epifaunal macrobenthos of seagrass meadows form an important trophic pathway to higher predators *via* the decapods. Although absolute predation intensities remain unknown, the primary pathway of transfer to higher trophic levels differs between the 2 habitats—through the epifauna in seagrass meadows, and through the infauna in bare sand bottoms.

Acknowledgments—R.G. Gilmore allowed use of his unpublished data on fishes from the present study site and, along with W.G. Nelson, S.A. Bloom, A.W. Stoner and R.K. Howard, provided helpful reviews. C.B. Lounibos illustrated Fig. 4. Harbor Branch Foundation Contribution Number 281.

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OBSERVATIONS ON THE ECOLOGY AND REPRODUCTION OF THE SIPUNCULAN *PHASCOLION CRYPTUS* IN THE INDIAN RIVER LAGOON

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Abstract: *A study of the most abundant sipunculan found in the Indian River Lagoon,* Phascolion cryptus *Hendrix, 1975, was conducted on a monthly basis from June 1976 through May 1977. These animals, which inhabit discarded gastropod shells in shallow water, were found in densities of 667 to 3,856/m² at a station 9.25 km north of the Fort Pierce Inlet, Florida. Adult* Phascolion *were common in shells of 5 species of gastropods. Most frequently they inhabited* Cerithium muscarum *shells which comprised an average of 85% of those available for inhabitance. Population numbers were not limited by shell availability. Reproductive activity was estimated by the developmental state of coelomic gametes and spawning in the laboratory. Animals were reproductive throughout the year with a trend for higher reproductive activity from November through May. Juveniles, commonly occupying shells of* Bittium varium, *comprised 37 to 58% of the population during winter, spring and summer, decreasing to an average of 15.5% in the fall.*

The sipunculan *Phascolion cryptus* Hendrix, 1975, is a common inhabitant of the Indian River estuary on the central, east-coast of Florida. It is a small species (3 cm in extended length) living in discarded gastropod shells in a manner similar to that of hermit crabs (Fig. 1). When the sipunculan feeds or moves about, the anterior end or "introvert", is extended through the aperture of the shell, while the rest of the body remains inside. Usually

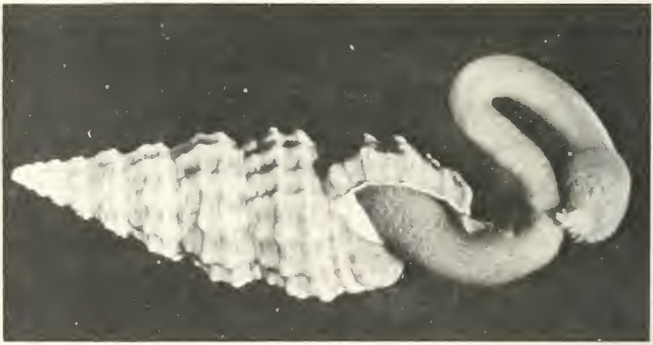

Fig. 1. *Phascolion cryptus* adult in a shell of *Cerithium muscarum*. Introvert bearing a crown of tentacles is extended from the aperture of the shell.

buried within the upper 5 cm of the sediment, the sipunculan may stretch its introvert to the surface of the sediment or above. Thus extended, the crown of tenacles terminating the introvert may function for feeding on suspended particulate materials and for the exchange of respiratory gases through the tentacular wall.

Phascolion cryptus occurs in large numbers along the length of the Indian River in sandy bottom areas, frequently with a cover of seagrasses. In a study of community structure of the macrobenthos associated with seagrass beds in the Indian River, Young and Young (1977) ranked this species third in order of abundance at a station near Haulover Canal, and forth at both the centrally-located station near Link Port, and the more southerly station near the St. Lucie Inlet. Of the percentage of total individuals in the top-ranked 10 species at these 3 stations, *Phascolion cryptus* comprised 11, 9, and 6%, respectively from north to south.

We investigated selected features of the ecology and reproduction of *Phascolion cryptus* for 1 yr at the Link Port station. In monthly collections we noted densities, occurrence in habitats of bare sand or seagrasses, and the utilization of shells of different sizes and of different gastropod species. In the laboratory we observed the behavior of the animal in relation to its occupied shell. As an indication of reproductive activity, we recorded at monthly intervals in field-collected specimens the sizes of coelomic oocytes, states of differentiation of coelomic sperm, and spawnings of laboratory-maintained animals.

MATERIALS AND METHODS—This study was conducted from June 1976 to May 1977 in the Indian River Lagoon north of the Link Port canal, 9 km north of the Fort Pierce Inlet, Florida at latitude 27°32.1'N, longitude 80°20.9'W. The collecting area was characterized by sandy patches amidst grass beds dominated by *Halodule wrightii* (shoal grass). Water depths at the time of collection ranged from 2 to 59 cm. Temperatures ranged from 12.5 to 38°C and salinities from 16 to 35‰.

For measurements of density, a sampling grid was established covering an area of 12 × 24 m where 3 or 4 replicates were collected at monthly intervals for 1 yr. At the initial collection, a rope 24 m in length was stretched in an east-west direction between 2 fixed points and samples were taken at 6 m intervals from the easternmost point towards the shoreline on the west. Samples in succeeding months were taken at points 1 m due north of the previous month's collections. Samples were collected with a stainless steel sampling device which isolated sections of the bottom 5 cm in depth and 15 × 15 cm in surface area (Fig. 2). Upon collection, the samples were transferred to 1 mm mesh bags and material less than 1 mm in size was sieved out at the collecting site. Samples were sieved through 2.8, 2.0 and 1.0 mm wire mesh sieves in the laboratory, and gastropod shells trapped by each sieve were collected and counted. The number of uninhabited and *Phascolion*-inhabited shells retained by each sieve was recorded for use in density and shell occupancy determinations.

Animals were collected just outside the density sampling grid for measurements of reproductive activity. Gastropod shells were cracked in a vise to extract the *Phascolion cryptus*. Coelomic contents of adults (i.e., animals over 20 mg wet wt) were sampled by piercing the posterior end of the animal with a needle while holding the specimen above a droplet of sea water on a microscope slide. The pierced end was then touched to the droplet as the animal was squeezed gently. A coverslip, supported at the corners by bits of modeling clay, was placed over the preparation. Ten females were sampled each month and for each female the first 50 oocytes encountered in the microscopic survey of the slide were measured. An average of 9 males (range, 5-13) was sampled each month for the presence of free coelomic sperm. Animals of both sexes in the 2 larger size classes in the density study and any excess animals from the collections for

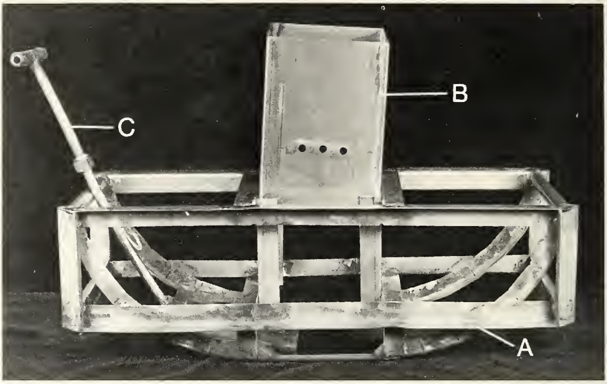

Fig. 2. Stainless steel sampling device for density study. Sampler is pushed into the sediment until stopped by rim (A) which is 5 cm above the bottom of the sampler. The 15 × 15 cm corer (B) is inserted and the shovel (C) is guided along the track to cut off the bottom of the core sample at 5 cm depth. The sampler is then raised and the sample dropped into an open 1 mm mesh bag for sieving.

reproductive measurements were maintained in the laboratory for 2 mo and observed for spawning.

Methods used in laboratory studies of behavior of *Phascolion cryptus* will be presented in the Results section along with an account of the observations.

Density—The number of *Phascolion cryptus* per square meter ranged from 667 to 3,856 at the Link Port station from June 1976 to May 1977 (Fig. 3). Although measurements of density showed considerable monthly variability, a higher density was found in June 1976 at the beginning of the study than in May of the following year. The greatest decrease occurred between August and September 1976. A breakdown of total density into densities of each of the 3 size classes indicates that the decrease in September was due primarily to the diminished numbers of juveniles (Fig. 4). The lack of concomitant increase in the larger size classes points to a possible loss of juveniles from the population, rather than growth of individuals. During the last few months of the study (March through May) the relative numbers of juveniles and adults were essentially the same as those of the first few months (June through August), despite the overall decrease in actual densities of both large and small size classes during the year (Figs. 4, 5).

Monthly collections usually contained samples from both bare-sand areas and areas covered by seagrass beds comprised of *Halodule wrightii*. Densities were consistently higher throughout the year in seagrass beds than in sandy areas outside of the seagrass (Fig. 6).

Shell Occupancy—At the Link Port station *Phascolion cryptus* of the 2 upper size classes were commonly found in discarded shells of 5 species of gastropods. They were, in order of abundance at the collecting site:

Cerithium muscarum, *Nassarius vibex*, *Modulus modulus*, *Neritina virginea*, and *Marginella apicina*. The shells of *C. muscarum* occurred in the greatest numbers, constituting 84% of the shells available for occupancy by *P. cryptus*. Thirty-nine percent of the *C. muscarum* shells were actually occupied by *P. cryptus*. The abundance of *Modulus* and *Marginella* shells was markedly less than *Cerithium*, but the percentage occupancy of these shells by *Phascolion cryptus* was not significantly different from that of *Cerithium* (Table 1). The remaining 2 gastropod shells, *Nassarius vibex* and *Neritina virginea*, had a significantly lower occupancy by *P. cryptus* than *C. muscarum* (Table 1). The smallest sipunculans were found predominantly in shells of *Bittium varium*.

An examination of the percentage occupancy of shells in each of 3 size classes shows that with increasing shell size, there is an increasing percentage of available shells occupied (Fig. 7). This difference in percentage occu-

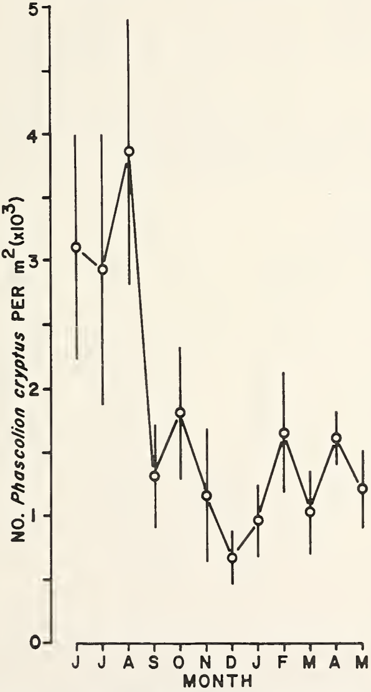

FIG. 3. Density of *Phascolion cryptus*. Monthly averages of the total numbers of individuals per square meter, including all size classes, from June 1976 to May 1977. Standard error bars are shown.

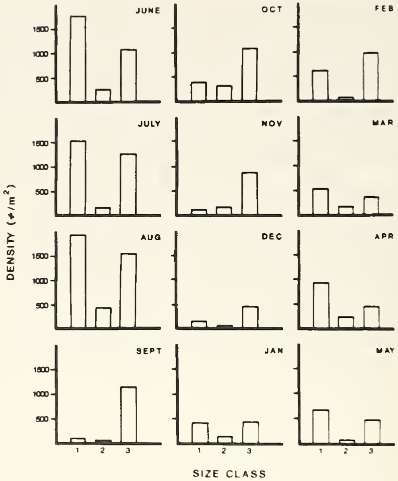

FIG. 4. Monthly densities of the 3 size classes of *Phascolion cryptus* from June 1976 to May 1977. Size classes 1, 2 and 3 represent *Phascolion* in gastropod shells of sizes from 1.0 to 2.0 mm, 2.0 to 2.8 mm and greater than 2.8 mm, respectively.

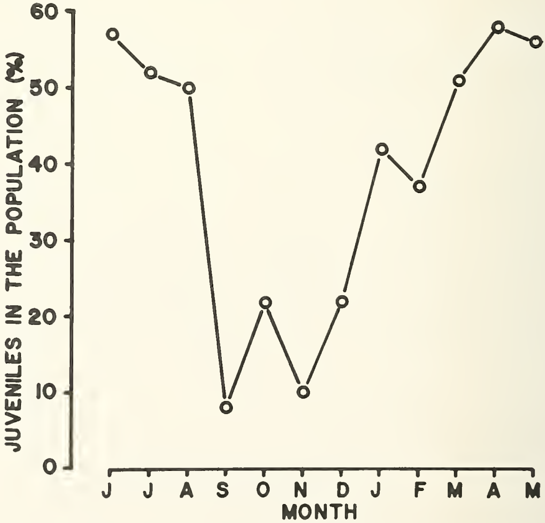

FIG. 5. Percent of *Phascolion cryptus* juveniles (in 1 - 2 mm shells) in the population from June 1976 to May 1977.

TABLE 1. Shell species most commonly inhabited by *Phascolion cryptus* (excluding the 1.0-2.0 mm size class). Tested differences (χ^2, df = 1) in shell occupancy between *Cerithium muscarum* and each of the 4 other shell species are indicated.

Shell Species	Total No.	No. Occupied	% Occupied	X^2	Significance
Cerithium muscarum	1198	464	39	—	—
Modulus modulus	85	28	33	1.18	ns
Marginella apicina	23	9	39	0.00	ns
Nassarius vibex	94	26	28	4.67	$0.01 < P < 0.05$
Neritina virginea	57	3	5	26.30	$P < 0.01$

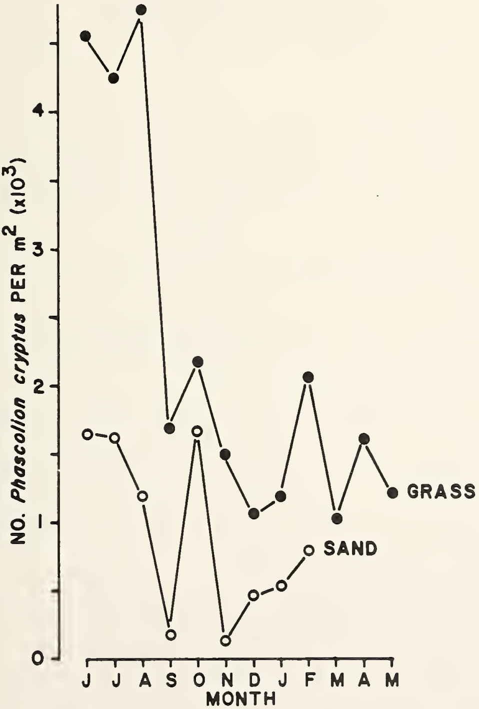

FIG. 6. Density of *Phascolion cryptus* in beds of *Halodule wrightii* (Grass) and bare sand (Sand) from June 1976 to May 1977.

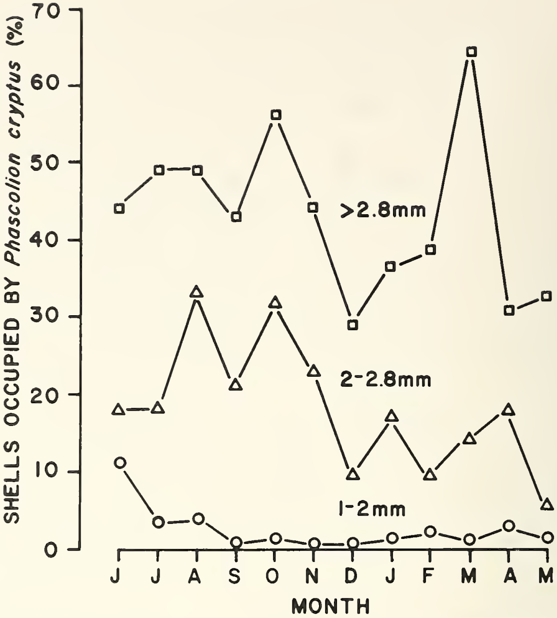

Fig. 7. Percent of discarded gastropod shells occupied by the 3 size classes of *Phascolion cryptus* from June 1976 to May 1977.

pancy in the 3 size classes persisted throughout the year in spite of monthly variations for each size class. Never were all of the available shells occupied. The highest percentage occupancy in any of the size classes was 66.5 which occurred in the largest size class in March.

The behavior of animals in relation to their shells was investigated in a series of 3 laboratory experiments. In the first 2 experiments, 12 animals (7 in experiment 1 and 5 in experiment 2) were extracted from their shells by cracking the shells in a vise. Each *Phascolion cryptus* was then immediately placed in a 10 cm culture dish in the center of a circle of 6 empty shells. The shell apertures were towards the center of the circle and were equidistant from the animal. Shell apertures presented to half of the animals were directed down against the bottom of the dish and those presented to the other half were directed upward. Shells used were of comparable size and of the same species as those from which the animals had been removed. In 11 dishes, the shells were *Cerithium muscarum* and in 1 dish *Marginella apicina*. Animals and shells were placed in dishes of sea water without substratum in experiment 1, and with substratum in experiment 2. The substratum, obtained from the Link Port collecting site, consisted of a thin layer of silt overlying 1 cm of sand. Once the animals were exposed to the empty shells, they were watched continually and their behavior was recorded and timed.

In experiment 1, specimens which had been removed from their shells entered empty shells by inserting the introvert into the aperture and pulling the more posterior trunk into the shell. Of the 7 animals observed, the times for choosing a shell ranged from 14 min to over 7 hr, and the elapsed time from the beginning of entry until the animal disappeared completely into the shell ranged from 3 to 7 min. Once in a shell, the animal turned around and extended its introvert from the shell aperture. This turn-around time ranged from 11 to 18 min in the 6 cases in which animals entered *Cerithium* shells and was 6 min in the case of the animal that entered a *Marginella* shell.

In experiment 2, animals burrowed into the sediment and extended their introverts above the substratum to select the empty shells. Times for shell selection ranged from 30 to 86 min for the 5 animals observed. Once inside the shells, animals eventually buried themselves and the shells they inhabited 3-7 mm below the sediment level. Though all the animals in these 2 experiments entered empty shells, only 1 in 12 entered the first encountered shell.

In the third experiment, the spires of shells containing *Phascolion cryptus* were removed in a vise. The remaining shell was approximately one-half its original length and the posterior end of the animal was exposed. The 6 animals in this experiment were placed in culture dishes of sea water next to an intact empty shell of similar size and of the same species as that which it was inhabiting. Two empty shells were added to the 5 dishes in which no shell exchange had occurred by Day 2. An additional 2 shells were added to the 1 dish in which no shell exchange had occurred on Day 10. In time, all animals left the damaged shells and entered intact, empty shells. The time required for this exchange ranged from 1 to 9 da.

REPRODUCTIVE BIOLOGY—Samples of coelomic fluid taken at monthly intervals revealed that gametes in some stage of differentiation were present in most animals (greater than 20 mg in wt) throughout the year. Free spermatozoa were present in the coeloms of at least 70% of the male population except in August when the percentage was only 13 (Fig. 8). For 6 mo out of the yr, coelomic spermatozoa were found in 100% of the males examined. Small oocytes, from 20 to 110 μm in dia, were present throughout the year, suggesting that the ovary was continually productive. Large oocytes (110-140 μm) showed a general increase in percentage from a low in summer to a high in winter and spring (Fig. 9). This trend corresponded with the decrease in laboratory spawning activity in summer months and with the low percentage of juveniles in the population in the fall (Figs. 4, 5). Animals spawned in the laboratory in every month of the year, however, the lowest activity was in the summer and the highest in the fall.

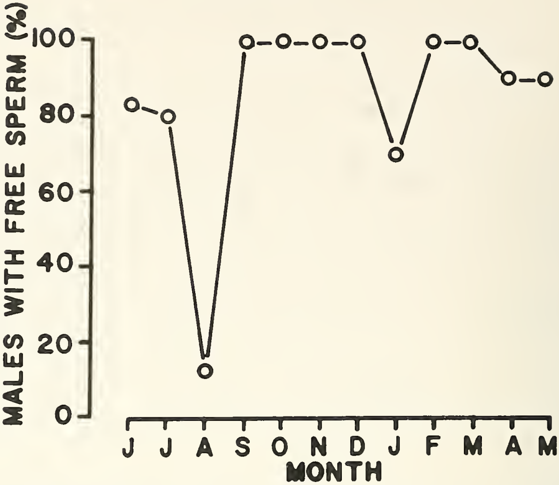

FIG. 8. Percent of *Phascolion cryptus* males with free coelomic sperm from June 1976 to May 1977. (Number of males observed each month equals, respectively, 12, 6, 8, 5, 5, 13, 10, 10, 10, 10, 10, 10).

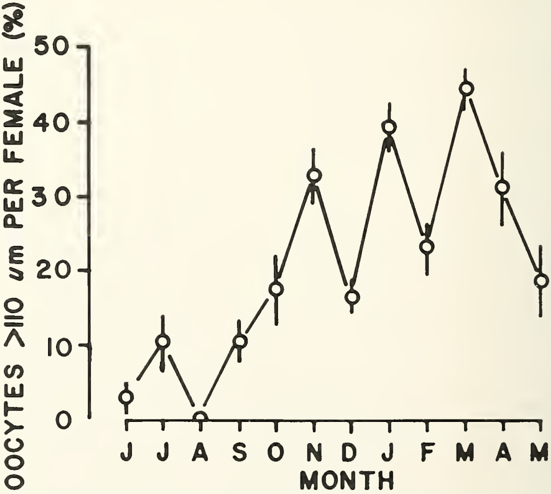

FIG. 9. Average monthly percentage of large oocytes (> 110 μm dia) per female. Each month, 50 oocytes from each of 50 females were measured (a total of 500 oocytes per month). Standard error bars are shown.

DISCUSSION

DENSITY—Densities for *Phascolion cryptus* have been measured by other investigators at the Link Port station, and such measurements fall within the range found in this study (667-3,856/m²). In a long-term survey of the benthic ecology of the Indian River, Virnstein (pers. comm.) found densities which averaged 2,271/m², the average for the same period in our study was 1,776/m². The density reported by Young and Young (1977, 1978) as a value for controls in their experimental studies was 2,400/m². These densities for *P. cryptus* are the highest recorded for any sipunculan species. Another species of the same genus and of comparable size, *Phascolion strombus*, was reported in densities ranging from 60 to 135/m² in waters 45 m in depth off the west coast of Sweden (Hylleberg, 1975). A large sand-burrowing species, *Sipunculus nudus*, which reaches lengths of 30 cm (Stephen and Edmonds, 1972) has been reported to have an average density of 4.6/m² on a sandy beach at Morgat, Bay of Douarnenez, Brittany, France (Edmonds, 1962). Rock-boring species from the Caribbean Sea, *Aspidosiphon brocki* and *Lithacrosiphon alticonum*, were found in densities as great as 900 and 500/m², respectively (Rice and Macintyre, 1982, Fig. 3).

The explanation for the overall decline of density in the population of *Phascolion cryptus* during our study is unclear. The sharpest reduction occurred in the juvenile population between the August and September measurements. Because the drop was unaccompanied by a corresponding increase in the larger size classes, we assume that it could not be due entirely, if at all, to growth of juveniles. Moreover, the abruptness of the decline leads us to speculate that some external factors, such as extremes of temperatures and salinity or heavy predation, were causative factors. An examination of readings made at the time of the September collection, show that the salinity was 16‰, lowest for the year and the temperature was 25 °C, among the highest for the year. Further suggestion for the importance of these environmental factors comes from the experiment of Hylleberg (1975) on the cold-water population of *Phascolion strombus*. He demonstrated that this species could not tolerate combinations of high temperatures (above 16 °C) and low salinities (below 23‰). Although *P. cryptus* occurs in warm waters, in view of these findings a further consideration of the tolerances of the species, especially of juveniles, would seem warranted.

The continued low numbers of juveniles from September through December (Figs. 4, 5) follows the summer period of low reproductive activity of adults and is most likely explained by a lack of production of young animals. The recovery of the juvenile population and its overall increase from December to May is consistent with increased reproductive activity of the population in fall and winter.

Our finding of *Phascolion cryptus* in greater densities among *Halodule wrightii* than in areas of bare sand agrees with other reports of high densities of macrobenthos in seagrass beds (O'Gower and Wacasey, 1967; Orth, 1977). In a study of animal communities associated with seagrass and sand beds in Biscayne Bay, O'Gower and Wacasey (1967) found a far greater abundance of species in seagrass. Among these enumerated was a species of *Phascolion*, later described as *Phascolion cryptus* (Hendrix, 1975) which occurred in *Halodule* beds in densities 13 times greater than in areas of bare sand in Virginia Key. Moreover, *P. cryptus* was the dominant benthic species in these *Halodule* beds.

Orth (1977) emphasized the importance of the stabilization of sediment by seagrass beds in Chesapeake Bay as a factor related to increased density of macrobenthos. He proposed that by impeding the flow of waves and currents and thus reducing erosion, the seagrass prevents juveniles and adults from being resuspended and transported away from their habitats. Young and Young (1978) further examined the sediment-stabilizing function of seagrass beds in studies at Link Port. In a series of field experiments testing the regulation of species densities of seagrass-associated macrobenthos, they tested the effect of removal of the blades of *Halodule wrightii*. They found that *Phascolion cryptus* differed from several other species in that it was not markedly affected by clipping of grass blades. The authors reasoned that stabilization of the sediment provided by the rhizomes was of greater importance to this species than protection or other factors provided by the blades. Other experiments in the same study compared the density of macrobenthos under caged and uncaged conditions in the field and showed little response by *P. cryptus* to the exclusion of predators by caging. More recently, however, Nelson (1981) has demonstrated that 2 species of decapod shrimp may prey on *P. cryptus*. He studied decapod and fish predation on macrobenthos associated with seagrass both in laboratory tanks and in predator inclusion cages in the field at the Link Port station. Of the predators tested, *Penaeus duorarum* and *Palaemonetes intermedius* significantly reduced the number of *P. cryptus* in laboratory tanks, though their effect in field experiments was not significant.

SHELL OCCUPANCY—Of the 37 reported species of *Phascolion*, most occupy discarded gastropod shells. The rest are found mostly in polychaete tubes or in mud and sand tubes of their own construction (Stephen and Edmonds, 1972; Hendrix 1975). Similar to the occupancy of shells by hermit crabs (cf., Reese, 1962; Scully, 1979; Bertness, 1980), the occurrence of *Phascolion* in certain species of shells may reflect, at least in part, abundance and diversity of available shells in the area. And, like hermit crabs, *Phascolion* may show some preference for certain species of shells within a habitat, although evidence is conflicting in this regard. Hylleberg (1975) found *P. strombus* to occur in shells of all species of gastropods as well as a scaphopod that inhabited the study area in the Gåsö Ränna Channel, Kristineberg, Sweden. No evidence for shell selection was detected for this species. *Phascolion cryptus* at the Link Port site was also found in all of the most commonly occurring shells. However, differences in the percentage occupancy by *P. cryptus* of the commonly available shells suggests that this sipunculan might display some degree of selectivity for different species of shells (Table 1). Though *P. cryptus* showed by far the greatest percentage occupancy in the most abundant shell, *Cerithium muscarum*, its relative occupancy of the shells of *Nassarius vibex* and *Neritina virginea* was significantly lower. Percentage occupancy of 2 other shells, *Modulus modulus* and *Marginella apicina*, on the other hand, was not significantly different from that of *C. muscarum*. The reason for this apparent shell selection is not evident from our data. Morphology of shells, in terms of shape and size of aperture, length of spire, number of whorls and extent of cavity, is so variable among the 5 species that this seems an unlikely basis for shell selection. Future experimental observations, considering these and other factors such as size, shape, and weight of shells, are necessary before selectivity of different species of shells can be understood or verified in *P. cryptus*.

Selection of shells on the basis of size, or the exchange of smaller shells for larger shells, has been documented with greater certainty for *Phascolion* by both field and laboratory observations. The finding in the field of immature specimens of juveniles in smaller shells and of adults in larger shells indicates that *Phascolion* changes shells as it grows. Moreover, laboratory studies show that an animal will leave its protective habitat when space is diminished. Hylleberg (1975) maintained *P. strombus* in syringes from which the tip had been cut, and over a period of time he gradually decreased the space in the syringe by a periodic increase of pressure on the plunger. When the contracted animal completely filled the available space, it left the syringe. Similar results were found in our laboratory experiments on behavior of *P. cryptus* when the spire of the occupied shell was removed, thereby decreasing the size of the available habitat and exposing part of the animal. Under these circumstances the sipunculan left the damaged shell and entered an available intact shell.

Exchange of shells in the field has not been observed, nor have specimens without shells been found in field collections. Presumably during periods of exchange when the animals lack the protection of shells, or are in damaged shells, susceptibility to predation is increased. In our laboratory experiments, once animals were removed from their shells, the minimum time for them to enter other shells was 14 min and the maximum time over 7 hr. This was under presumably ideal conditions when empty shells were provided close to the shell-less animal within a small dish. In the field where empty shells might not be so readily available, the period without a shell or with a damaged shell might be prolonged, thus increasing the time of exposure to predation. Or perhaps in the field an animal retains its shell until it locates a more appropriate shell. Further investigations are indicated for an understanding of the significance of shell exchange in the avoidance of predation, and the developmental history of the individual.

Shell availability was not found to be a limiting factor for *Phascolion cryptus* in our study in which the highest percentage of occupied shells was found to be 66.5. However, the study by Hylleberg (1975) on *P. strombus* off the west coast of Sweden suggests that shell availability may be limiting for that species. He found occupancy of available shells in the Swedish population to be 90%. As in hermit crabs (cf., Kellogg, 1976; Scully, 1979; Bertness, 1980), percentage occupancy by *P. cryptus* increased with increasing size of shells (Fig. 7). Although not noted in previous studies, our investigations of *P. cryptus* showed that the dominant shell species in the 2 larger size classes was *Cerithium muscarum*, whereas in the smallest size class it was *Bittium varium*. Thus the growth of this population of *P. cryptus* is dependent on the co-existence of at least 2 species of gastropods.

Reproductive Biology—Most sipunculans, including *Phascolion cryptus*, are dioecious. Gametes are detached at an early stage of differentiation from a minute gonad attached to the body wall and complete their development as independent cells in the coelom. By assessing the state of differentiation of coelomic gametes (measuring oocytes or classifying stages of developing sperm) over 1 yr we found *P. cryptus* to be reproductively active throughout the year with a period of reduced activity in the summer. Annual reproductive cycles of 5 other species of sipunculans have been delineated by year-long observations of coelomic gametes. They are: the temperate species *Golfingia minuta* (Gibbs, 1975), *G. vulgaris* (Gonse, 1956), *G. pugettensis* (Rice, 1975a) and 2 populations of *Phascolosoma agassizi* (Towle and Giese, 1967; Rice, 1975a) and the tropical species *Phascolosoma arcuatum* (Green, 1975). In contrast to *Phascolion cryptus*, a subtropical species, all have definitive breeding seasons. Most of the species, including *P. cryptus*, have oocytes in the coelom throughout the year, suggesting that ovaries are continually active; however, oocytes of large sizes usually appear only prior to and during the breeding season. There are 2 exceptions, *Phascolosoma arcuatum* and a population of *P. agassizi* from Monterey Bay, California, in which the small oocytes disappear for 2 mo after the breeding season. Of these animals in which annual reproductive cycles have been ascertained, only *Phascolion cryptus* has large oocytes throughout the year, although in the summer the average percentage is low. Measurements of coelomic gametes from other temperate species, *Golfingia elongata*, *G. rimicola*, and *G. margaritacea*, made over only parts of the year but spanning spawning periods, suggest that breeding seasons for these species are also limited (Gibbs, 1976).

Estimates of reproductive activity have been made in other sipunculans by observations at all seasons of the year on spawning of animals maintained in the laboratory (see Rice, 1975a for review). By such observations, estimations of breeding seasons have been made with some degree of certainty for 5 additional species: *Phascolion strombus* (Akesson, 1958) and *Themiste pyroides* (Rice, 1975a) from temperate waters and *Phascolosoma perlucens*, *Themiste alutacea* (Rice, 1975b) and *Themiste lageniformis* (Rice, 1975a) from tropical or subtropical waters. The 2 temperate species have restricted breeding seasons, whereas the tropical/subtropical species appear to breed throughout much of the year. Thus, from the information available, it would appear that *Phascolion cryptus* follows the pattern for most tropical and subtropical sipunculans in that it breeds during most of the year.

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Academy Symposium

A PHYSICAL DESCRIPTION OF LONG-PERIOD NET DISPLACEMENT VARIATION WITHIN THE SOUTHERN INDIAN RIVER LAGOON, FLORIDA

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Abstract:*Meteorological and hydrographic data were recorded over a 29-da period in the summer of 1981 to describe wind effects on long-period net displacement of water along the navigational channel of the southern Indian River lagoon, Florida. Tidal motions decreased with increasing distance from the ocean inlets at either end of the study area, enhancing wind effects. Tidal current speeds in the middle of the study area were 50% of those at the Fort Pierce Inlet, while the nontidal current variance increased by 27% over the same distance, and by 64% over that at the St. Lucie Inlet. A net displacement of water toward the north throughout the study area was coherent with windstress over time scales in excess of 2 da.*

Dyer (1973) reviewed criteria established by Pritchard (1955) and Cameron and Pritchard (1963) to classify estuaries by their stratification and salinity characteristics. Since 1960, descriptions of estuaries have shifted toward dynamic characteristics based upon net circulation as well as stratification (Hansen and Rattray, 1960, Bowden, 1978). In this study, a description of net flow is based upon low-frequency wind effects. Current data reveal characteristics similar to those described by Dyer (1973) for coastal lagoons. Compared to other parts of the Indian River (Smith, 1982), the southern Indian River lagoon has fewer spoil islands, less variation in the orientation of the navigation channel, greater width and no point sources of fresh water. Smith (1982) observed flow characteristics between the Fort Pierce and Sebastian Inlets and found that areas distant from ocean inlets exhibit periods of slight net displacement related to variability in local winds. My research supports this finding, although net displacement in the southern Indian River is larger and more consistent in direction from one station to the next. Hydrographic differences from one study to the next may account for observed differences in flow patterns.

The Indian River lagoon extends 195 km along the central Florida Atlantic coast. The southern Indian River is that portion between the 2 southernmost inlets (Fig. 1). This bar-built estuary is separated from the ocean by Hutchinson Island and is 42 km long. The St. Lucie River empties into the Indian River at the southern end of the study area. Fresh water can enter the southern Indian River from the St. Lucie River during flood control releases from the Okeechobee canal system.

The Southern Indian River is 1.6 to 3.2 km wide. Water depths are as great as 180 cm near the navigation channel, becoming shallower toward shore. The Intracoastal Waterway is 3 m deep and 50-60 m wide with well defined sides rising 30° from the horizontal. The channel is closer to the western shoreline, with large grassflat areas and coves on the east side. The navigation channel has a heading of 354° from the mid station northward, and 159° from the mid station southward. Flow along these 2 headings will be referred to as northerly and southerly, respectively.

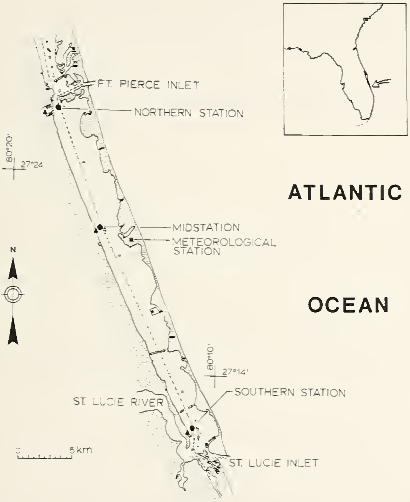

Fig. 1. Map of the study area showing the 3 water level recorders (triangles), the 3 current meter locations, the meteorological station, and their relative positions. The hatched lines delineate the Intracoastal Waterway.

Current data were obtained from 3 stations. The northern station was 4.6 km south of the jetties at the Fort Pierce Inlet along the navigation channel, the middle station was 15.9 km from the Fort Pierce Inlet and 26.2 km from the St. Lucie Inlet, and the southern station was 5.6 km north of the St. Lucie Inlet.

Some basic differences in geomorphology exist between the 2 inlets. The Fort Pierce Inlet is hydraulically stable and resists shifting and shoaling. Its avg depth is 6 m. The St. Lucie Inlet is not hydraulically stable (Harris, 1980) and requires periodic dredging. The avg depth of the St. Lucie Inlet is 1.8 m.

DATA REDUCTION AND PROCESSING—General Oceanics Model 2010 film recording inclinometers were deployed from 27 June to 31 July, 1981, to quantify and describe the long-period net displacement of water along the Intracoastal Waterway. Current meter inclination and direction were recorded at half-hour intervals. All current meters were 1 m above the bottom and situated similarly relative to topographic and structural features. Periodic survey dives confirmed proper installation and operation.

Reduction and analysis of current meter records began after inclination angles and current headings were digitized. Current speed and direction were determined to the nearest 1 cm/sec and 1°, respectively. Current vectors were decomposed into Cartesian coordinates, and only long-channel components were used in the analysis. Half-hourly data were smoothed with a triangular filter (filter weights of 0.25, 0.50 and 0.25), a process known as "hanning". Timing errors were removed and data were subsampled at hourly intervals. Following data reduction, a 29-da portion of hourly, long-channel currents from each location was compared with the meteorological data.

To isolate nontidal motions, current data were filtered with the 39-weight Doodson-Warburg filter described by Groves (1955). High frequency noise in the nontidal record was removed with a 5-weight binomial filter. The percentage of nontidal variance was quantified as the ratio of the variance computed after filtering to that computed before filtering.

The displacement of water past each current meter was computed by multiplying the current speed, in km/hr, by the 1 hr sampling period. Cumulative net displacement at each station was quantified for time intervals of 1-14 da. Cumulative histograms (Smith, 1982) were constructed to describe long-period characteristics of the flow.

Surface and mid-depth drogues were tracked along the Intracoastal Waterway during ebb and flood conditions. Drogue data were obtained to document vertical shear in the current moving along the navigation channel, and this to determine the representativeness of the near-bottom inclinometer data.

Hourly water levels were recorded with a precision of ±3 mm using Leupold and Stevens Type A water level recorders located along the west shore adjacent to each current meter station. Water levels were digitized relative to an arbitrary datum, and clock errors were removed.

Hourly wind speeds and directions were recorded to the nearest 1.6 km/hr and 1°, respectively, at a weather station near the middle of the study area (Fig. 1). Instrumentation was 18 m above the water surface. Wind vectors were converted to hourly windstress vectors (Wu, 1980), and the long-channel component was used in the analysis.

Energy density spectra were computed, using the fast-Fourier technique described by Fee (1969). Coherence and phase spectra were obtained from the long-channel windstress and the long-channel current components from each station. A 29-da harmonic analysis of current and water level data (Dennis and Long, 1971) was carried out for each study site. Harmonic constants include the amplitude and local phase angle, and they may be used both to characterize and predict the tide at a given location (Schureman, 1958). In this study, only the principal semi-diurnal (M_2) constituent is discussed.

Results and discussion—Results of drogue tracking indicated no significant vertical shear along the Intracoastal Waterway. Longitudinal separation of the surface and mid-depth drogues were minimal. Greater separation was noted near the inlets during northerly flow and with northward directed winds. Under these conditions, the wind effect increased surface current speeds. When southerly currents were opposed by a northerly-directed windstress as well as by bottom friction, surface and mid-depth current speeds were similar. Long-channel components of the windstress (Fig. 2) are predominantly positive, indicating that during the study period the Atlantic coast of Florida was influenced by winds with headings into the northwesterly or northeasterly quadrants.

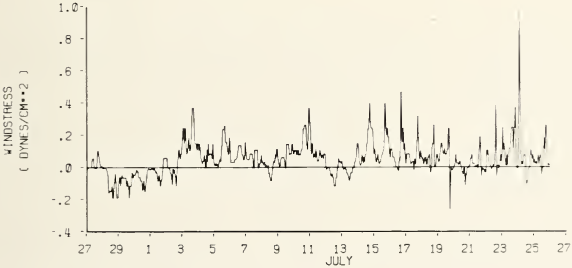

Fig. 2. Plot showing the long-channel component of the windstress. Observations are hourly, beginning at 0000 hr 27 June 1981, and ending 2300 hr 25 July 1981. Positive values indicate winds traveling south to north.

Long-channel currents at the northern station are shown in Fig. 3. At this location, the amplitude of the M_2 tidal constituent was 65 cm/sec, and the corresponding tidal excursion was about 10 km. Fig. 4 is of nontidal current speeds. Values range from 24 cm/sec to the north to 4 cm/sec to the south, with a quasi-periodic variation of 3-4 da. The nontidal current accounted for only 0.8% of the total current. Cumulative net displacements past the current meter (Fig. 5) are consistently to the north, indicating an outflow through the Fort Pierce Inlet. Minor oscillations in the plot are a

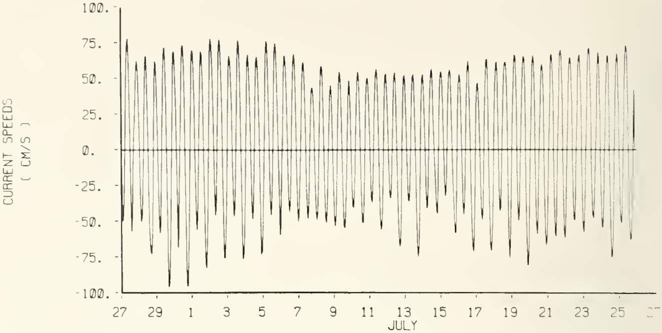

Fig. 3. Plot showing the northern station total long-channel currents from 0000 hr 27 June 1981, through 2300 hr 25 July 1981.

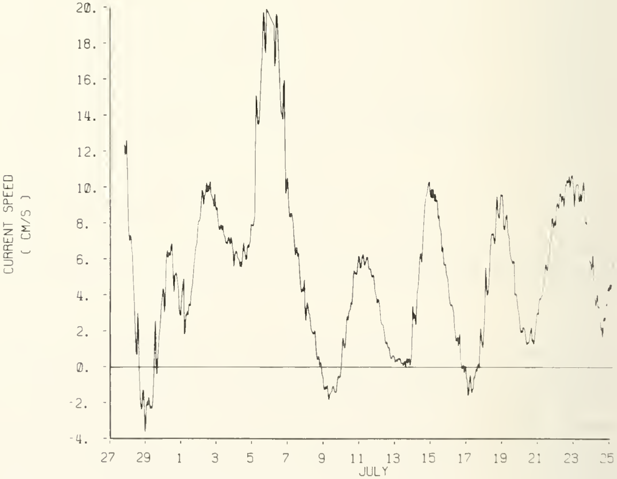

Fig. 4. Plot showing the northern station nontidal long-channel currents from 1900 hr 27 June 1981, through 0400 hr 25 July 1981. Positive values indicate currents traveling from south to north.

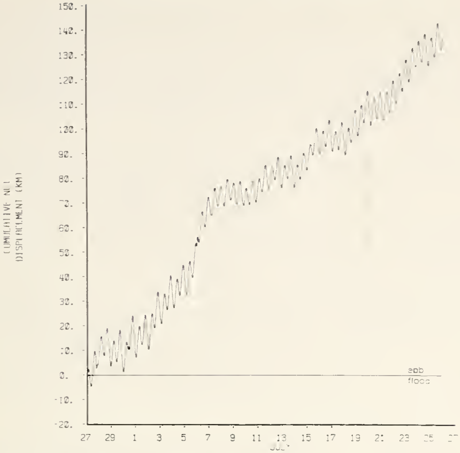

FIG. 5. Plot showing the northern station net displacement of water past the current meter from 0000 hr 27 June 1981, through 2300 hr 25 July 1981. Positive values indicate net displacement from south to north.

result of tidal excursions. Displacement during the ebb exceeds that during the flood, resulting in the net displacement to the north. Periods of nontidal net displacement to the south are rare, and they do not appear to last for more than a few days. The data indicate an average net displacement of 4.7 km/da toward the north during the study period.

Current patterns at the southern station (Fig. 6) are similar to those recorded at the northern station. Although the direction of the long-period net flow is the same at both locations, a northerly displacement at the southern station occurs with a net flow of water into the lagoon. The amplitude of the M_2 constituent at the southern station was 43.5 cm/sec, corresponding to a tidal excursion of approximately 8 km. This is about 67% of the value computed at the northern station. Nontidal currents (Fig. 7) ac-

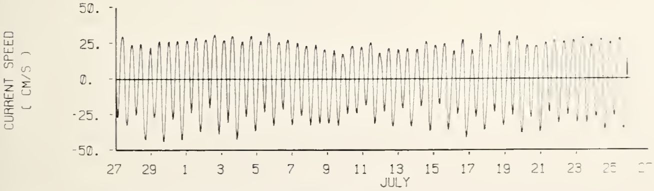

FIG. 6. Same as Fig. 3 except for the southern station.

counted for only 0.4% of the total current and ranged from 7.9 cm/sec to the north to 1.7 cm/sec toward the south. The plot of cumulative net displacement (Fig. 8) shows a general nontidal flow of water into the lagoon. Over selected periods of a few days, there may be a net displacement toward the south, but for all time intervals in excess of a week net displacement was to the north.

Long-channel currents at the midstation (Fig. 9) were slower than those at either of the other 2 study sites. The M_2 constituent amplitude was only 31 cm/sec, or 75% of that at the southern station and 50% of that at the northern station. Nontidal currents (Fig. 10) range from 5.1 cm/sec to the north to 6.5 cm/sec toward the south, and account for 1.1% of the total current variance. Nontidal motion is quasi-periodic over time scales on the order of 3-4 da. Net displacement over the entire study period is slightly to the north (Fig. 11), however, it varies greatly over shorter periods. A close comparison of the net displacement plots from each station shows similar low frequency trends, indicating that similar nontidal effects were experienced at all 3 locations.

Spectral analysis of windstress and long-channel current speed components show coherences statistically significant at the 95% confidence level at all 3 locations. Table 1 summarizes coherence-squared values for time scales in excess of 40 hr. At the middle station, windstress and current speed were coherent at periods of 67 hr and longer; at the northern station, statistically significant coherences were computed at periods of 67 and 100 hr only. Current data from the southern station were coherent with windstress for periods in excess of 200 hr.

Results of the harmonic analysis show a similarity in spatial variations of the harmonic constants of both current and water level data. The amplitudes of the M_2 constituent computed from the water level data at the northern, southern and middle stations were 14.8 cm, 10.2 and 8.8 cm, respectively. The amplitude at the middle station was 59% of that at the northern station and 86% of that at the southern station. Analysis of the current data at the middle station resulted in an M_2 amplitude 50% of that at the northern station and 75% of that at the southern station. Local phase angles for the M_2 constituent computed from water level data at the northern, southern and middle stations were 281°, 313° and 328°, respectively. It is evident that the tide at the southern station lags behind that at the northern station by 32°, or 1.1 hr. Similarly, the tide at the middle station lags 1.6 hr behind that at the northern station, and 0.5 hr behind that at the southern station. Results suggest that tidal damping and retardation at the St. Lucie Inlet is greater than that at the Fort Pierce Inlet. The 1.1 hr lag of water levels at the southern station behind those at the northern station is consistent with the greater tidal excursion calculated for the northern part of the study area. This suggests that, for tidal exchanges alone, the interface of water entering the southern Indian River through the 2 inlets is south of the true midpoint between the Fort Pierce and St. Lucie Inlets.

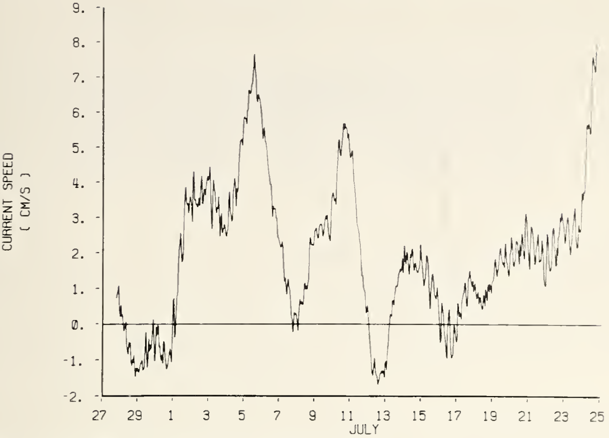

Fig. 7. Same as Fig. 4 except for the southern station.

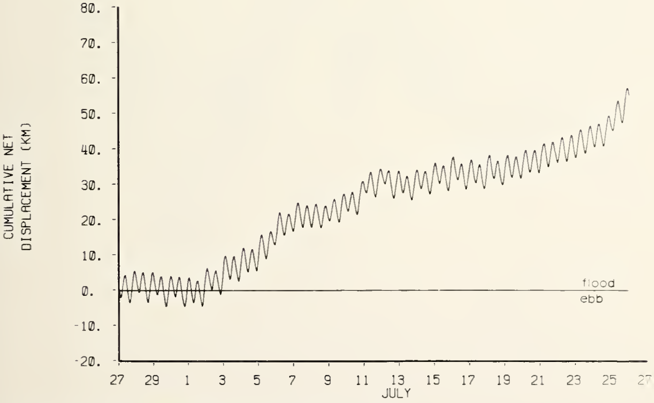

Fig. 8. Same as Fig. 5 except for the southern station.

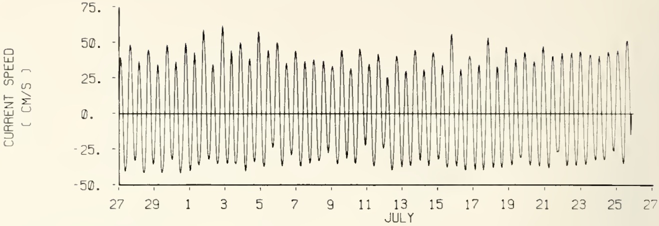

Fig. 9. Same as Fig. 3 except for the midstation.

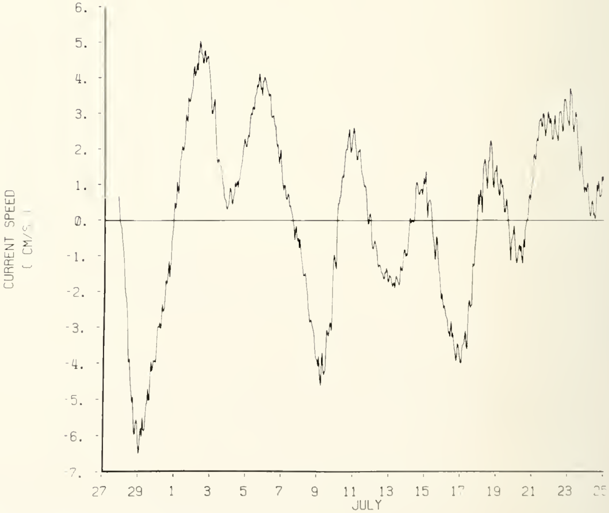

Fig. 10. Same as Fig. 4 except for the midstation.

Table 1. Coherence squared values from spectral analysis. 0.21 is significant at the 95% confidence level. Coherence values not significant at the 95% confidence level are shown in parentheses.

Station	Periodicity (hours)					
	40	50	67	100	200	1000
Northern	(0.138)	(0.170)	0.367	0.365	(0.192)	(0.123)
Southern	(0.153)	(0.144)	(0.111)	(0.161)	0.284	0.350
Midstation	(0.022)	(0.148)	0.333	0.361	0.289	0.373

Conclusions—The southern Indian River lagoon has net flow patterns similar to those described by Dyer (1973) for coastal lagoons. Tidal currents diminish with distance from the Fort Pierce and St. Lucie Inlets, and nontidal processes become increasingly visible and important for the net displacement of water over long time scales. Still, at all 3 locations, nontidal motions comprise a small fraction of the total current.

Statistically significant coherences between long-channel current and windstress components confirm that nontidal currents occur in response to windstress. Windstress appears to be of primary importance for the net displacement of water over time intervals of 2 da and longer during summer months.

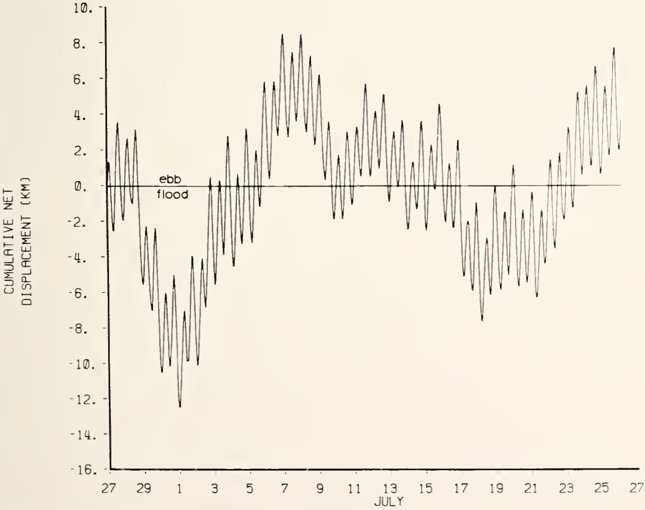

Fig. 11. Same as Fig. 5 except for the midstation.

Spatial variations in net displacement past the 3 current meter stations suggest that a temporary storage of water may occur in the lagoon, or that substantial net flows may exist outside the navigational channel. Future studies should concentrate on defining net flows in areas more distant from the Intracoastal Waterway.

Acknowledgments—Field assistance and support throughout the project were provided by Ned P. Smith. Ross Wilcox of Florida Power and Light Company provided the meteorological data. Harbor Branch Foundation, Inc., Contribution No. 280.

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Academy Symposium

DIEL VARIATIONS OF DISSOLVED AMMONIA AND PHOSPHATE IN ESTUARINE SEDIMENT PORE WATER

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Abstract: *Variations of dissolved ammonia and phosphate in pore water at depths of 2 to 40 cm were examined every 3 hr for 27 hr. Eh values were consistently negative and pH ranged from 7.2 to 8.0. Ammonium and phosphate were greatest at 10 cm and both steadily decreased to 40 cm. Maximum ammonium concentrations were 2.7 μM in surface water and 169 μM in the sediment. Maximum phosphate concentrations were 6.4 μM in surface water to 30.4 μM in sediment. Nitrate concentrations were 2.2 to 9.9 μM at 2 cm and 0.1 to 0.8 μM in surface waters. No nitrate was detected below 2 cm. Dynamic changes in the levels of phosphate and ammonium were observed during the period.*

Diagenetic processes help recycle nutrients in estuarine sediments. In shallow environments recycled phosphorus and nitrogen play an especially important role in estuarine primary production (Patriquin, 1972; Billen, 1978).

The role of macrophytes in controlling the flux of nutrients from sediments has been examined by various investigators. McRoy and Barsdate (1970) measured transport of dissolved reactive phosphate (DRP) from the roots and rhizomes of seagrass *Zostera marina* to the overlying water. The flux of DRP was 8 times greater in the light than in the dark. Nienhuis (1980) concluded eelgrass was not a "nutrient pump" in Netherland estuaries. Other investigators have examined estuarine systems and found no diel changes in inorganic nutrients (Nixon, et al., 1976), whereas some found large diel changes in nitrogen and methane (Oremland and Taylor, 1976). Nitrate uptake was determined to be dependent on light, whereas light did not affect ammonium uptake (Toetz, 1971). Diel rhythms for nitrogen fixation in the rhizosphere of *Thalassia testudinum* were noted by Capone and Taylor (1977, 1980).

Production and migration of the diagenetically produced nutrients, ammonium and DRP were shown to be controlled by the redox potential and pH of the sediment (Zicker et al., 1956; Fenchel, 1977; and Lu and Chen, 1977). The role and importance of ion exchange in regulating the transfer of phosphate between sediments and water was shown by Pomeroy et al. (1965), Carritt and Goodgal (1954). Rosenfeld (1979) found 1 to 2 times as much ammonium was adsorbed on the sediment as was dissolved in the pore water of nearshore sediments.

The importance of hydrostatic parameters in altering pore fluids was shown by Lee (1977). Seepage of pore fluids correlated significantly with water surface elevation.

METHODS AND MATERIALS—The sampling site was a *Halodule wrightii* seagrass bed at depths of 50-85 cm in the Indian River which was described by Gilmore (1977). The upper 15 cm of sediment was predominantly sand sized; below 15 cm the sediment is graded sand to clayey sand (Zimmermann and Montgomery 1980). Pore water was sampled every 3 hr for 27 hr from 0800 on 27 April to 1100 on 28 April 1978. The pore waters were collected using *in situ* pore water samplers and analyzed for ammonium, DRP, nitrate, nitrite, temperature, salinity, Eh and pH. A description of the sampler and detailed procedures for collection and analysis of anoxic pore waters for nutrients appears elsewhere (Montgomery et al., 1979).

Pairs of *in situ* samplers were placed 0.5 to 1 m apart in the sediment of the grass bed at 10, 20, 30 and 40 cm depths. They were allowed to equilibrate for 1 wk. Additional samples were collected from 2 cm depth using a modified syringe assembly (Johnson, 1967). Temperature and salinity of surface water and sediment were recorded. Surface dissolved oxygen was measured with a YSI Model 51 A oxygen meter, and tidal height noted during each time period from a tide staff.

Three replicate pore water samples for 10, 20, 30 and 40 cm depths were analyzed within 3 hr for ammonium, nitrate and nitrite, reactive phosphate, Eh and pH under an inert atmosphere (Montgomery et al., 1979). Nutrients were analyzed on a Technicon AutoAnalyzer II system using slightly modified Technicon procedures (Zimmermann et al., 1977).

Surface and 2 cm pore water samples were immediately filtered through acid-washed deionized water rinsed Nuclepore filters (0.4 μm pore size), Eh and pH determinations made and the sample stored at $-5°C$ for later analysis. Eh values are versus the standard calomel electrode. The frozen samples were analyzed for nutrients and salinity within 10 days.

RESULTS—The Eh and pH profiles are in Figs. 1 and 2. Sediment temperature profiles were ca. 22°C in the sediment and ranged from 20.5 to 23.5° in the surface water. The pore water salinity varied from 33 to 34 ppt at the 2 and 10 cm depth and was ca. 34 ppt at 20, 30 and 40 cm depths.

The concentrations of dissolved reactive phosphate and ammonia are in Figs. 3 and 4. The concentrations of nitrate plus nitrite and oxygen are in Table 1.

The analytical precision (RSD) between replicates was 3.0% and 4.8% for ammonium and DRP, respectively. Cochran's test for the homogeneity of variances was performed on the logarithmically (base 10) transformed ammonium, and DRP data. The results, at a $p < 0.05$ level, indicate that the pore water depth profiles of the various nutrients are real and not a sampling artifact. The correlation coefficient, r, between ammonia and phosphate, was $+0.857$ at 2 cm. No significant correlation was found between these 2 nutrients at the other depths. All data were logarithmically transformed.

Ammonium and DRP concentrations were integrated over depth for each sampling period. All correlation coefficients shown are significant at the $p < 0.05$ level. The total integrated ammonium from surface to 40 cm had a correlation of $-.765$ with tide. There was no correlation of DRP with tide unless the tide was lagged by 3 hr. The correlation of total integrated DRP (0 to 40 cm) with lagged tide was $+.614$. A correlation of $+.695$ was obtained for the integrated DRP with Eh over the interval from 10 to 40 cm. The correlation coefficient of the integrated DRP versus pH for the same interval was $-.862$.

The accumulation of DRP becomes noticeable between 2000 and 0800 when the integrated values of DRP for the interval from surface to 40 cm changes from an average of 0.27 moles cm^{-2} to 0.40 μ moles cm^{-2}. The accumulation of DRP between surface and 2 cm from 0800 to 1700 hr in-

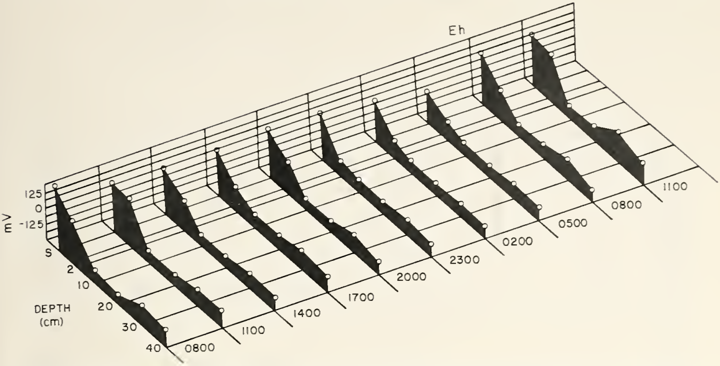

Fig. 1. Platinum electrode potentials, im mV, in surface water and sediment pore waters at 2, 10, 20, 30 and 40 cm from 0800 (27 April 1978) to 1100 hr (28 April 1978).

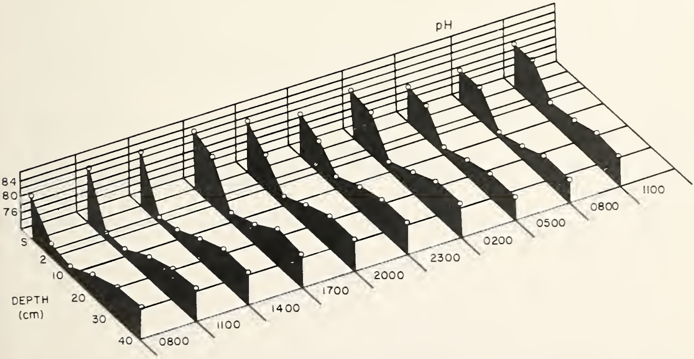

Fig. 2. pH Values in surface water and at 2, 10, 20, 30 and 40 cm from 0800 (27 April 1978) to 1100 (28 April 1978).

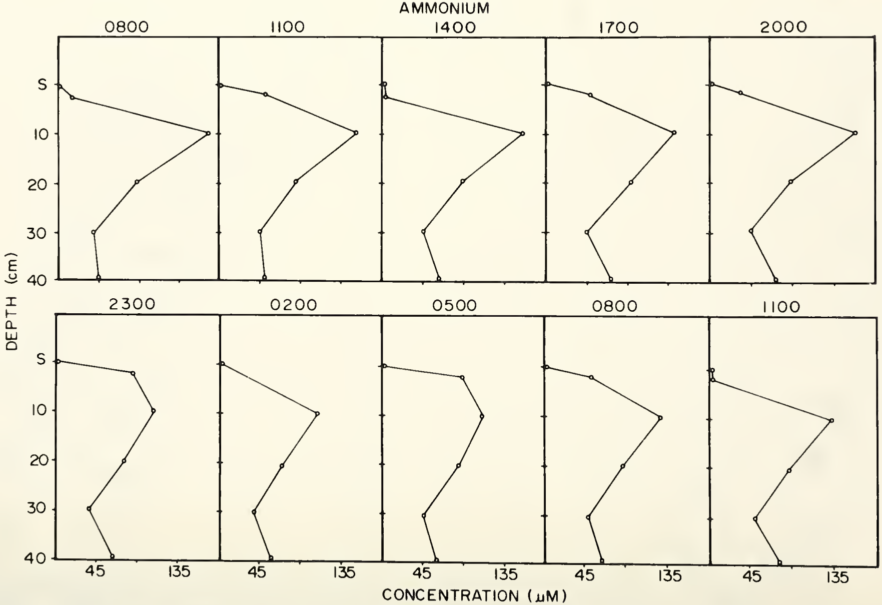

Fig. 3. Mean observed concentrations of dissolved ammonia (micromolar) in surface water and sediment pore waters at 2, 10, 20, 30 and 40 cm from 0800 (27 April 1978) to 1100 (28 April 1978). The sample at 0200 hr was lost.

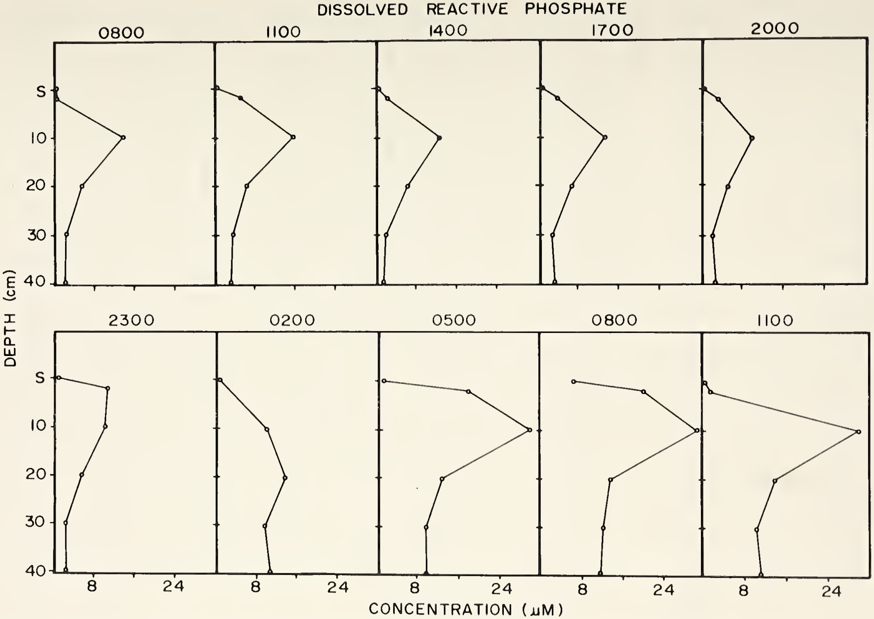

Fig. 4. Mean observed concentrations (micromolar) of DRP in surface water and sediment pore waters at 2, 10, 20, 30 and 40 cm from 0800 (27 April 1978) to 1100 (28 April 1978). There was no observed 2 cm value for the sample at 0200 hr.

TABLE 1. The tide height in cm, concentration of oxygen in mgl^{-1} for surface water, and concentration of nitrate plus nitrite in M for surface water and sediment pore water at 2 cm for 27-28 April 1978. The 24 hr clock was used for time units. No nitrate plus nitrite was detected below 2 cm in the sediment.

					Time, Hours					
Sample	0800	1100	1400	1700	2000	2300	0200	0500	0800	1100
Tide cm	50	60	70	60	48	68	82	72	55	60
Surface										
Oxygen	2.40	10.0	12.6	12.4	11.0	8.30	6.30	3.60	5.00	10.7
Nitrate plus Nitrite	0.29	0.37	0.43	0.25	0.17	0.26	0.31	0.25	0.77	0.46
Porewater, 2 cm										
Nitrate plus nitrite	6.5	2.8	3.4	2.8	3.5	3.7	*	3.5	2.4	2.2

Asterisk indicates lost sample.

creased from an average integrated value of 0.003 μ moles cm^{-2} to 0.010 μ moles cm^{-2} between 2000 and 0800 hr. Mean integrated ammonium values for the surface to 2 cm interval increased from 0.03 to 0.06 μ moles cm^{-2} during the same time period. Little discernable increase of integrated ammonium occurred at any of the other depth intervals during the night.

DISCUSSION—Diel changes in pore water ammonium and phosphate concentrations in the area of the *Halodule wrightii* seagrass bed are clearly apparent (Figs. 3 and 4). Several hypotheses could explain these changes. We have postulated that DRP and ammonium accumulate during dark periods because of decreases in soluble nutrient transport by the seagrass *Halodule wrightii*. As a result of sampling every 3 hr with *in situ* samplers with precisions of 5 of 7% (Montgomery et al., 1979) the variation for each sampler at each depth is best explained by changes in the concentrations of the nutrients rather than variation associated with the sampler. The data show that both ammonium and DRP accumulated at night and this accumulation was especially noticeable in the upper 10 cm.

Ammonium and DRP diagenesis parallel each other in many ways. However, DRP differs from ammonium in that it can precipitate to form authigenic minerals such as apatile and vivianite. Also under oxic conditions DRP does not undergo oxidation as does ammonium and is more strongly adsorbed than ammonium on hydrous ferric oxides (Berner, 1980).

When the Eh is lowered the concentration of DRP should increase (Stumm and Morgan, 1970). Our data show no correlation of DRP with Eh in pore waters between surface and 10 cm. A positive correlation of DRP with Eh was shown between depths of 10 and 40 cm, i.e., as the concentration of DRP increased the Eh became more positive. However, all the mean Eh values in this region ranged from -120 to -180 mv. The uncertainties of measuring Eh in pore waters probably mask any correlations of DRP with Eh. The negative correlation of pH with DRP indicates that as the pH decreases the DRP increases. According to Stumm and Morgan (1970, p. 548

and 559) increasing pH should cause a release of DRP from sediment. The maximum difference in pH during this period was only 0.28 pH units. In general phosphate reacts with Fe (III), Al (III) (clays) and Ca^{2+}, however little of the DRP would be adsorbed between pH 7 and 9 (Stumm and Morgan, 1970) so lack of positive correlation of pH with DRP may not be surprising.

The seagrasses, rather than acting as a nutrient pump may cause subtle changes in the redox conditions of the sediment. These subtle changes could affect the availability of DRP. Oremland and Taylor (1976) noted diel changes in oxygen, nitrogen and methane in sediments beneath *Thalassia testudinum*. The production of oxygen during photosynthesis and the transport of oxygen through the seagrass rhizomes to the sediment could alter pH and redox potential. Phosphate, iron minerals and hydrous ferric oxides are all interrelated through redox reactions (Einsele, 1936; Stumm and Morgan, 1970). Therefore, any changes in the redox potential could cause changes in available DRP.

The height of the tide above the sediment was negatively correlated to the total integrated ammonium. It is possible that hydrostatic pressure differences between ground water and Indian River water could produce an "apparent" change in pore water concentration. Lee (1977) measured a maximum seepage velocity in a Beaufort, NC estuary of 2 μm sec^{-1}. This is equivalent to a 2.1 cm change in pore water elevation over 3 hr. We have measured a maximum average interstitial seepage velocity for sediments with 50% water (by wt.) of 3.6 μm sec^{-1}. This magnitude of velocity could lead to a pore water movement of 3.6 cm over 3 hr. Therefore, if the 2 cm depth were sampled at time zero and again 3 hr later, the second parcel of pore water collected would be a parcel originally at 5.6 cm.

The negative correlation of total integrated ammonia with tide height seems to indicate that seepage flux may play a large role in the changes in ammonium concentrations over a diel time period. The lack of any correlation between ammonia and DRP as well as the lack of correlation of DRP with tide height seems to point to different mechanisms for the dynamic changes noted in ammonium and DRP concentrations. The positive correlation of total integrated DRP with a 3 hr lagged tide may be fortuitous but there is insufficient data at this time to explain this phenomenon.

As shown by our data, the diel variation of nutrients in pore waters could be due to a number of factors. It does appear, for this study, that DRP and NH_4^+ accumulate in sediment pore waters after photosynthesis ceases. However, it is not possible to disregard hydrostatic pressure differences caused by tides and their effect on the transport of dissolved nutrients.

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TRACE METALS IN THE INDIAN RIVER LAGOON, FLORIDA: THE COPPER STORY

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Abstract: *Inputs of copper from anti-fouling paints presently pose an environmental stress on some restricted embayments of the Indian River Lagoon, Florida. Over an 18 mo period, samples of water, suspended matter, sediments, barnacles, clams and crabs from selected sites along the Indian River and the Eau Gallie River, have been analyzed for copper. Higher than normal copper concentrations were consistently observed in the water column, sediments, barnacles and crabs collected from the Eau Gallie Harbor. Point sources of copper could be directly traced to vessel-related activities. From field data and laboratory experiments on the leaching of copper from anti-fouling paints, an estimated flux of 40 kg/yr to Eau Gallie Harbor was calculated. Up to 75% of the total copper input to the harbor may be retained there. Outside such tributaries along the Indian River from Vero Beach to Melbourne, copper levels were within normal limits.*

Copper is a micronutrient element fundamental to all forms of life; yet, in excessive amounts, it may become toxic to organisms by inducing a reduction in enzyme activity or a random rearrangement of structural proteins (Bowen, 1979). Large inputs of Cu from anti-fouling paints presently pose an environmental threat to restricted coastal embayments such as those found along the Indian River Lagoon, Florida. These inputs were evaluated and their fate was assessed within the Indian River System and its biota.

Copper based anti-fouling paints are applied to boat hulls to prevent the attachment and growth of organisms. The paints function by leaching Cu into the water fast enough to interfere with an organism's activity, yet not so rapid as to exhaust the Cu in a short time. An effective leaching rate is usually quoted at 10 μg Cu/cm^2 of hull/da (Goldberg, 1976). At that rate, Goldberg (1976) estimates a global input of Cu to the marine environment from anti-fouling paints to be 2500 metric tons per yr. Although this anthropogenic addition is only 1% of the natural flux, the influence of anti-fouling paint Cu may be especially evident in harbors, coastal embayments or shipping lanes. For example, Young et al. (1979) found Cu levels in selected tissues of the bay mussel *Mytilus edulis* to be up to 10 times above normal levels in some Southern California Harbors.

Barber and Trefry (1981) suggested similar problems for harbor areas along the Indian River Lagoon, Florida. That preliminary work has been extended to provide a more detailed picture of the behavior of Cu in a typical harbor setting and the migration of pollutant Cu into the open Indian River System.

Methods—Field sampling for our Cu study was carried out from November 1978 through

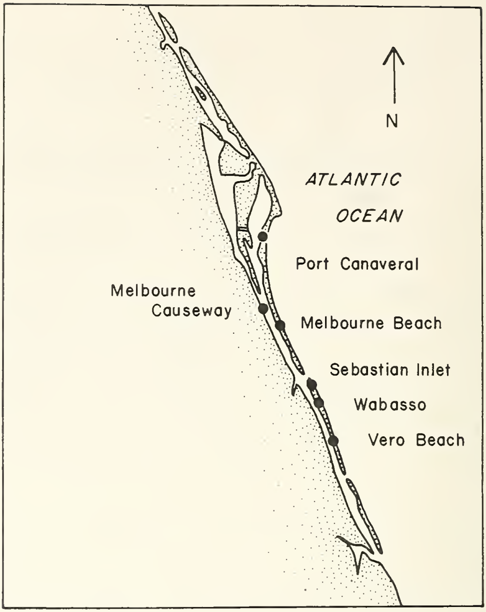

Fig. 1. Map of the Indian River Lagoon showing sampling sites.

May 1980 at selected sites along the Indian River Lagoon (Fig. 1) and one of its tributaries, the Eau Gallie River (Fig. 2). Samples collected for Cu and other metal analyses included water, suspended particulates, bottom sediments, barnacles, crabs and clams. Extreme care was taken throughout the sampling and laboratory efforts to minimize random metal contamination. *In situ* measurements of selected hydrographic parameters (salinity, temperature, pH and dissolved oxygen) were also made throughout the study period using standard techniques (Strickland and Parsons, 1972). Water samples were generally collected in duplicate from the bow of a small fiberglass boat moving slowly upwind. The samples were obtained from about 15 cm below the surface by direct filling of acid-washed, 500 ml conventional polyethylene bottles. Immediately upon return to the laboratory, suspended particulates were separated from the unacidified samples by filtration through preweighed, acid-washed, Nuclepore membranes (47 mm dia, 0.4 μm pore size). Suspended matter loads were quantified by reweighing the filters following drying/equilibration. The filters were stored in plastic petri dishes prior to particulate metal analysis and the filtrate was acidified with 250 μl of concentrated, double distilled HNO_3 and saved for dissolved Cu determination.

Dissolved Cu species were extracted from solution using the cobalt-ammonium pyrrolidine dithiocarbamate (APDC) coprecipitation technique of Boyle and Edmond (1975). Sample preparation was carried out in a clean room which is separated from the main lab by double doors and serviced with HEPA-filtered air. Following extraction, the filter-precipitates were placed in polystyrene vials to which 0.5 ml of concentrated, double distilled HNO_3 was added to dissolve the Co- APDC precipitate. The solution was then diluted to 15 ml with distilled-dionized water and analyzed for Cu by atomic absorption spectrophotometry (AAS) using a Perkin Elmer 460 instrument equipped with a Model 400 heated graphite atomizer, an AS-40 auto-sampler, and a deuterium-arc background corrector. Analysis of spiked water samples showed Cu recov-

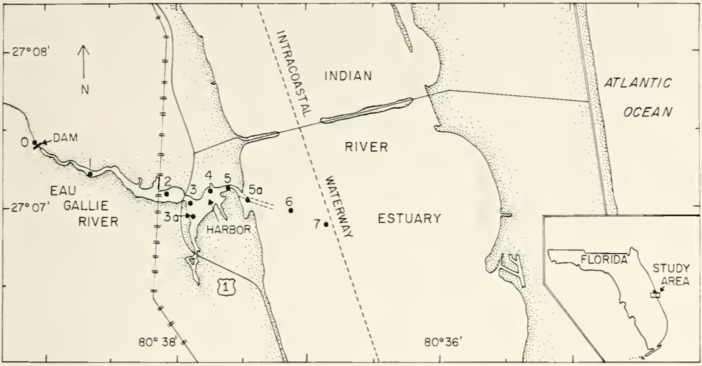

Fig. 2. Map of Eau Gallie River and Harbor and adjoining Indian River Lagoon showing sampling sites. Inset map of Florida identifies location of study area.

ery by the co-precipitation technique to average better than 95%. All copper in organisms, sediment or dissolved and particulated phases of the water were analyzed by AAS.

Suspended particulates were digested in 15 ml, stoppered teflon tubes using concentrated HF and redistilled HNO_3 and heated in a hot water bath.

Sediment samples were obtained directly from 0.5 to 1.5 m water depths using either 10 cm dia, 40 cm long plastic core liners or by sampling the top 10 cm of sediment with a polyethylene scoop. Subsamples (1 to 2 cm long) were carefully sectioned and freeze-dried. Sediment metals were analyzed for Cu and Fe by AAS following complete digestion with HF-HNO_3-$HClO_4$ or a partial leach with 1N HNO_3.

Barnacles from naturally occurring communities of *Balanus eburneus* were scraped directly from their substrata and placed in acid-washed polyethylene bags. After return to the laboratory, barnacles were thoroughly rinsed with distilled water to remove excess detritus. Whole soft parts were removed, weighed and pooled according to site for each determination. Samples were placed in acid washed 180 m*l* tall-form Pyrex beakers and digested with redistilled HNO_3 and 30% H_2O_2. The resulting clear solution was brought to a volume of 25 ml with distilled-deionized water. Procedural blanks were prepared following the same methods used for the barnacle digestions. Blue crabs (*Callinectes sapidus*) were collected in high density plastic traps. Dissection of claw and gonad tissue was carefully carried out in the clean lab and sample digestion and copper analysis followed the techniques described above for the barnacles.

Five to 20 clams (*Mercenaria mercenaria*) were collected at each site per sampling trip. The clams were immediately placed in acid-washed polyethylene bags and frozen. In the lab, thawed clams were removed from their bags, drained for a half minute and shucked. Whole clam soft tissues and carefully dissected individual organ tissues were placed in 180 ml tall form Pyrex beakers and digested with concentrated HNO_3 and 30% H_2O_2 and/or $HClO_4$. To check our accuracy, NBS oyster and tuna samples are frequently analyzed and our values for Cu are always well within the certified range. For the variety of analyses reported above, our precision is consistently better than 10%, commonly below 5%.

EAU GALLIE HARBOR—The Indian River Cu story unfolds at any one of many harbors or embayments where sizeable marinas or boat-repair facilities are located. For the purposes of this paper, the Eau Gallie River and Harbor (Fig. 2) serve as a useful example. Samples of water, suspended matter, sediment and barnacles were taken at the 10 sites identified in Fig. 2. Sites 3, 3a, and 4 are in the harbor proper, the location of several marinas

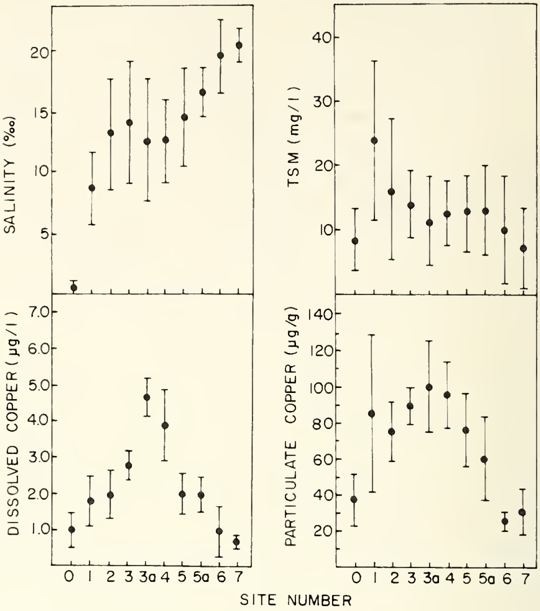

Fig. 3. Distribution of surface water salinities, total suspended matter (TSM), dissolved Cu and particulate Cu at Eau Gallie/Indian River sampling sites.

and a boat repair facility. Locations, 0, 1 and 2 are upstream of the harbor in the Eau Gallie River. A dam just below Site 0 serves to restrict upstream migration of saline water. Sites 5, 5a, 6 and 7 follow the mixing of water from the harbor with that of the open Indian River Lagoon. Water depths range from < 1 to about 3m throughout the area.

A partial view of the hydrographic setting for the above sample sites is given by the plot of surface water salinities in Fig. 3. The plotted values show means (with standard deviations) for monthly samples collected from January through May, 1980. Salinity increases along the study transect from Site 0 to Site 7, with the mid-study area (Sites 2 to 4) showing the highest degree of variability, a function of freshwater runoff. Water temperatures ranged from 16 to 30.5°C for the 5 mo period depicted in Fig. 3; however, temperatures varied by only 2 to 4°C across the sample transect during a given sampling trip. Surface water pH averaged 7.3 ± 0.2 in the fresh waters at Site 0, whereas the grand average for all the other stations was 8.2 ± 0.3. Dissolved oxygen concentrations were generally near saturation values in the surface water samples with up to a 50% reduction in near-bottom waters.

Total suspended matter concentrations are seasonally and spatially variable but show a general decrease from Station 1 to Station 7. The overall range of values was from 1.4 to 34 mg/*l* with a grand average of 13 ± 8 mg/*l*.

COPPER DISTRIBUTIONS AND INPUTS TO THE EAU GALLIE HARBOR—Dissolved Cu concentrations along the Eau Gallie/Indian River study area ranged from 0.4 to 5.6 μg/*l*. The extremely high values were consistently obtained in the immediate area of several boat marinas at Sites 3, 3a and 4 (Fig. 3). Subsequent dilution of these peak levels is brought about by mixing with the lower Cu containing freshwater or seawater end-members represented by Sites 0 and 7, respectively. Dissolved Cu values for these end-members were typically on the order of 0.4 to 0.6 μg/*l*.

Similar to the dissolved Cu trend, particulate Cu concentrations were highest in the harbor area (Fig. 3) where values averaged 90 to 100 μg Cu/g of suspended matter and ranged as high as 130 μg/g. In contrast to the harbor values, upstream and downstream waters had suspended matter Cu levels averaging about 30 μg/g. The combined dissolved/particulate Cu data show that particles transport 30 to 50% of the total Cu in the upper river and 20 to 30% of the total in the central harbor and Indian River Lagoon.

The peak concentrations of dissolved and suspended particulate Cu shown in Fig. 3 are clearly traceable to the marinas and boat-repair facilities in the harbor. To help evaluate the magnitude of these sources, the rate of Cu release from a common brand of marine paint used locally was measured. Pieces of wood with a known surface area were treated with the 55% Cu_2O paint and then placed in aquaria filled with Eau Gallie Harbor water. The average Cu leaching rate was found to be 12 μg Cu per cm^2 of painted surface per day. From the present boat population of the area (∼ 130 boats), a flux of 110 g Cu/da to the harbor waters was estimated.

This Cu flux, which is so evident in water column dissolved and particulate phases (Fig. 3), is also clearly discernible in the harbor sediments. Concentrations as high as 200 μg Cu/g sediment were found in the central harbor (Station 3A, Fig. 4). At Station 3A, sediment Cu values of 150 to 200 μg/g persist over the top 24 cm of the sediment column (Fig. 4), interrupted only by a 6 cm thick low Cu containing shell layer. Away from the central harbor, the depth extent of anomalously high Cu levels is restricted to the top 5 to 10 cm (Fig. 4, Stations 1 and 3) at levels of 50 to greater than 100 μg/g. At depth in the Eau Gallie Harbor sediments and outside the harbor in the open Indian River (Stations 5a, 6 and 7), sediment Cu concentrations are more typically <2 to 15 μg/g.

To put the Eau Gallie Harbor sediment Cu concentrations in perspective, average continental crust has an estimated 55 μg Cu/g (Taylor, 1964), Mississippi River suspended matter has 45 μg Cu/g (Trefry and Presley, 1976), and the E.P.A. limit for Cu in disposal sediments is 50 μg/g (E.P.A., 1973). Thus, by most standards or comparisons, the harbor sediments typically have 2 to 4 times greater Cu concentrations.

COPPER IN EAU GALLIE HARBOR BIOTA—The biological ramifications of the observed Cu inputs to the Eau Gallie Harbor were first identified in the ivory barnacle *Balanus eburneus* (Barber and Trefry, 1981). During this initial work, Cu levels in barnacle soft tissue were found to range from 11 to 64 μg/g (dry wt) when dissolved Cu concentrations were 0.4 to 1.6 μg/*l*. Fig. 5 shows that average Cu levels in barnacles collected from January to August, 1979, dramatically increase on approach to harbor Site 3 from either the upstream or downstream directions. Within-site variations over the 8 mo period (6 separate sampling trips) were surprisingly slight (Fig. 5). This temporal uniformity was especially evident at Sites 6 and 7 where the mean (± standard deviation) of 14.6 ± 0.6 μg/g most likely defines ambient barnacle Cu concentrations in this region. According to Fig. 5, then, Eau Gallie Harbor barnacles (Station 3) are enriched in Cu by a factor of 4 relative to the open Indian River Lagoon specimens.

The trend of barnacle Cu concentrations versus site (Fig. 5) is coincident with that shown for dissolved and particulate Cu in Fig. 3 and again distinguishes the harbor as an obvious point source of Cu. Barber and Trefry (1981) note a significant correlation between dissolved Cu and barnacle dissolved Cu as the key to Cu accumulation in barnacle soft tissues. No significant correlation (at $p = 0.05$) was found between particulate Cu (expressed in μg Cu/*l* water or μg Cu/g particles) and barnacle Cu.

One recent analysis of barnacle tissue collected in the area of Site 3A, where dissolved Cu concentrations are on the order of 5 μg/*l*, yielded 120 μg Cu/g (dry wt). This observation nicely extends the linear relationship between dissolved and barnacle Cu and shows that some harbor barnacles have almost 10 times higher Cu loading than open Indian River specimens. Available data from other studies in other areas (Walker et al., 1975; Bar-

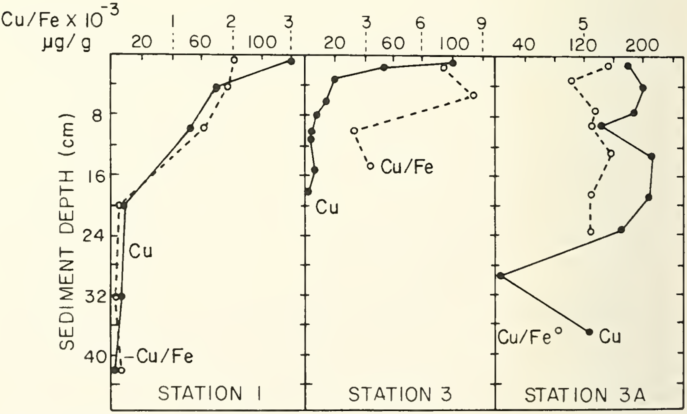

Fig. 4. Sediment total Cu profiles at Eau Gallie River and Harbor Sites 1, 3 and 3A.

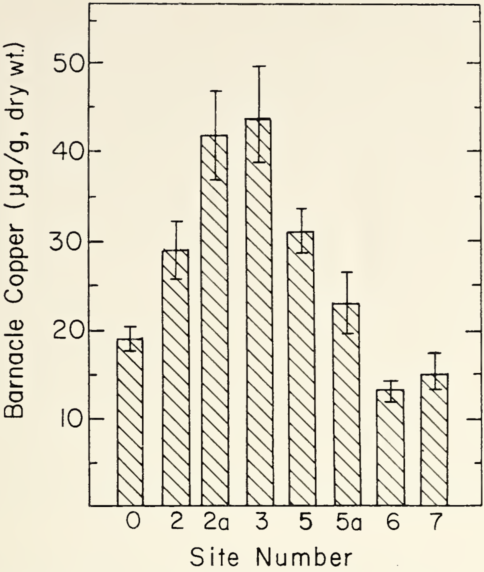

Fig. 5. Barnacle soft tissue Cu concentrations for specimens collected at Eau Gallie/Indian River sampling sites.

baro et al., 1978) show barnacle Cu ranges to be from 46 to 3750 µg/g (dry wt). Although the Eau Gallie Harbor barnacles certainly do not approach observed high values, the order-of-magnitude increase over background levels in the area certainly warrants concern.

To augment the barnacle study, Cu distribution in the commercially important and more commonly eaten blue crab *Callinectes sapidus* was also investigated. In this second look at the biota, a test of the hypothesis that transient species such as the blue crab can assimilate pollutant Cu during sojourns into polluted areas was made. Crabs were sampled in the Eau Gallie Harbor (Site 3, Fig. 2) and in the open Indian River near Melbourne Beach (Fig. 1). From February to May 1980, 14 individuals from the harbor setting and 19 from the open estuary were trapped and analyzed for the Cu content of the left and right claw and gonadal tissues.

Claw tissue from the Eau Gallie Harbor crabs averaged 75 ± 45 µg Cu/g (dry wt), about 70% higher than the 45 ± 20 µg/g value for the Indian River crabs (Table 1). High variability was common to both data sets (Table 1) and thus application of an F-Test to the 2 populations showed that they could not be statistically separated at the 95% confidence level. Nevertheless, the ∼ 70% higher mean and median values between the 2 environments certainly suggests some carry-over of the harbor's Cu perturbation to the transient crab population.

Within the claw tissue data sets is an interesting relationship between right and left claw Cu concentrations from the same individual. Despite the ranges in claw tissue Cu concentrations for both environments, a strong linear relationship was observed between the left and right claw Cu values from crabs collected in the harbor ($r = 0.98$, $p = 0.05$) and the river ($r = 0.6$, $p = 0.05$). The slope of the regression line in each data set was 0.7. These data support a strong covariance in Cu uptake by an individual's claw tissue and may provide future insight to the biochemical and environmental parameters which yield the observed ranges in Cu concentrations.

The Cu difference between the 2 environments was much more evident in the gonad tissue as harbor values (125 ± 55 μg/g) were significantly different (at $p = 0.05$) from those in the open river system (55 ± 35 μg/g). Although the range of values was sizeable in both cases, the Eau Gallie Harbor spread was double that of the Indian River population. Because the gonads are located within the abdominal cavity above the gill plates, they are directly exposed to water column Cu during gas exchange and may be more immediately responsive to environmental changes. More importantly, because the gonads are the key to reproduction and perpetuation of the population, the 2.5 times greater Cu concentrations in the harbor crabs is of some concern.

The above discussion does support the initially stated hypothesis that the transient blue crab can assimilate Cu above normal levels while in polluted, restricted embayments such as the Eau Gallie Harbor. Other studies of Cu in the blue crab claw tissue from "non-polluted" areas have shown means of 54 μg/g (dry wt) for San Antonio Bay, Texas (Trefry et al., 1976) and 34 μg/g (dry wt) for the Southeast coast of the USA (Windom, 1972). Thus, the open Indian River organisms are well within these values, whereas the Eau Gallie Harbor concentrations are somewhat higher.

COPPER DISPERSION TO THE INDIAN RIVER LAGOON—Water column and barnacle Cu data (Figs. 3 and 5) show that the peak values found in the Eau Gallie Harbor (Sites 3a and 4) are drastically reduced at open Indian River Sites 6 and 7. These trends imply that a limited amount of the anthropogenic Cu load of the harbor is dispersed to the open lagoon and/or that any Cu efflux to the open system is quickly mixed and diluted.

Sadoughi (1980) has synthesized a Cu mass balance estimate for the Eau Gallie-Indian River System using an "arrested saltwedge flow" model (Officer, 1976), wherein the flow velocity in the upper layer is much larger than in the lower layer. The Eau Gallie saltwedge has been shown (Meyer, 1977) to have a sharp halocline typically at 0.5 m, with 16 ppt salinity water in the upper layer and 24 ppt water in the lower layer. Meyer (1977) found near zero water velocities at the density interface with increasing velocities toward the surface. Upstream freshwater input to the Eau Gallie Harbor ($\sim 4 \times 10^6$ l/da) mixes with some 7×10^6 l/da of saline water intruding from

TABLE 1. Eau Gallie Harbor and Indian River crab sizes and Cu concentrations for claw and gonad tissue.

Location	Tissue	No. of Samples	Copper (μg/g, dry wt.)			Crab size (mm)
			Mean ± S.D.	Median	Range	(Mean ± S.D.)
Eau Gallie Harbor	Right claw	14	76 ± 48	72	25 to 190	146 ± 22
	Left claw	12	74 ± 50	69	25 to 185	142 ± 14
	Gonads	14	124 ± 53	118	30 to 195	147 ± 24
Indian River Lagoon	Right claw	19	45 ± 22	40	15 to 105	147 ± 19
	Left claw	17	47 ± 22	44	3 to 100	144 ± 16
	Gonads	19	49 ± 16	50	20 to 70	145 ± 20

the Indian River to produce a resultant intermediate salinity water outflow of 11 × 10^6 *l*/da over the arrested saltwedge. By coupling the water flow data with total Cu values, Sadoughi (1980) estimated the following Cu inputs to the harbor: (1) 6 g/da from the Indian River, (2) 5 g/da from freshwater sources and (3) 110 g/da from anti-fouling paint inputs. Of this approximately 120 g Cu/da influx to the harbor, only ∿ 30 g/da are calculated to leave the harbor with the outflowing intermediate salinity water. Thus, an estimated 75% of the total Cu input to the harbor is retained there, with about 25% flushing out into the open estuary.

Harbor sediments are the logical sink for the Cu retained there. The observed high Cu levels in the Eau Gallie Harbor suspended matter (Fig. 3) and sediments (Fig. 4) support this contention. Furthermore, during the laboratory Cu leaching experiments, a significant percentage of the released Cu (15 to 25%) was taken up by the particles on a 1 da time scale. Coupling these observations with Sadoughi's (1980) estimated 11 day flushing time for the Eau Gallie Harbor reinforces this particulate removal mechanism. To assess the magnitude of the sediment Cu reservoir, the Cu anomalies in the sediment column were integrated using sediment profiles (such as those in Fig. 4) for 7 different areas of the Eau Gallie system. The total excess sediment Cu (above background levels) in the harbor (area = $1.16 \times 10^9 \mathrm{cm}^2$) was calculated to be 830 kg. If 75% of the pollutant Cu flux (i.e. ∿ 82 g/da) is removed to the sediments, it would take about 30 yr to amass the estimated Cu burden. This estimate does not, however, attempt to factor in additions of Cu to the harbor during boat scraping and painting activities.

The preceding discussion serves merely to support the idea of limited flushing of pollutant Cu from such embayments as the Eau Gallie Harbor to the open Indian River. This limited migration of Cu away from the source area leaves its mark on the water, sediment and biota of the harbor, thus minimizing the effect on the estuary at the expense of the harbor.

Lower dissolved Cu levels immediately outside the Eau Gallie River mouth (Fig. 3) at 0.4 to 0.8 μg/*l* are typical of values found along the stretch of open Indian River from Vero Beach to Melbourne. Although these levels are higher than open ocean values of 0.1 μg/*l* or less (Bruland, 1980), they are not indicative of a large build-up of dissolved Cu. Particulate Cu concentrations in the Indian River commonly range from 0.1 to 0.6 μg/*l* and the high particle load of these lagoonal waters (~ 10 mg/*l*) favors the removal of dissolved Cu to particle surfaces. The resultant picture at this time is thus one of modest Cu levels throughout the main estuary.

Sediment Cu values along the open Indian River System at the sites studied (Fig. 1) typically ranged from < 1 to about 15μg/g and are certainly well below the values of 100 to 200 μg/g in the Eau Gallie Harbor and also below continental crustal abundances (55 μg/g; Taylor, 1964). Although our sediment surveys to date are not extensive, we have not yet identified any Cu-rich deposits comparable with the harbor data set.

Assimilation of Cu by the biota of the open Indian River Lagoon was also investigated using the clam *Mercenaria mercenaria*. For the 6 Indian River sites sampled between Vero Beach and Melbourne (Fig. 1), whole clam Cu concentrations averaged 5.4 ± 2.0 μg/g (dry wt). Mean values were spatially and temporally uniform (Fig. 6) over this region; and, using analysis of variance statistics, no significant differences in metal concentrations between these sites were identifiable (at $p = 0.05$, $F = 0.56$). Despite this apparent conformity of the Cu data set, a sizeable range in values (1.5 to 9.8 μg/g) was observed. These variations are best explained as a function of clam size (or age), since a significant negative correlation ($r = -0.60$, $p = 0.05$) was determined for size versus Cu content. Thus, a rather tight data set emerges for this stretch of the lagoon.

In sharp contrast to the Indian River values discussed above, Cu concentrations in clams collected from the Port Canaveral Turning Basin (Fig. 1) were significantly higher with a range of 9.9 to 20.7 μg/g and a mean (± S.D.) of 17 ± 5 μg/g (Fig. 6). The Port is a moderately industrialized area and, though separated from the Indian River by locks and a dredged channel, does serve as one source of saltwater for the lagoonal system. Relative to clam Cu data from Chesapeake Bay ($\bar{x} = 11 \pm 4$ μg/g; Larsen, 1979) or an average for the east coast of the U.S. from Maine to North Carolina ($\bar{x} = 13$ μg/g; Pringle et al., 1968), the Indian River values (5.4 ± 2.0 μg/g) are noticeably low and suggest minimal anthropogenic perturbations. The Port Canaveral data set, however, does support a measurable pollution influence.

Summary and conclusions—Our Indian River Cu story begins with point-source inputs of pollutant Cu from marine anti-fouling paints. Copper-based paints leach Cu into the surrounding water from vessel hulls at a rate of ∿ 12 μg/cm² of painted surface/da. Detailed studies in the Eau Gallie Harbor show that the pollutant Cu input to that area is about 110

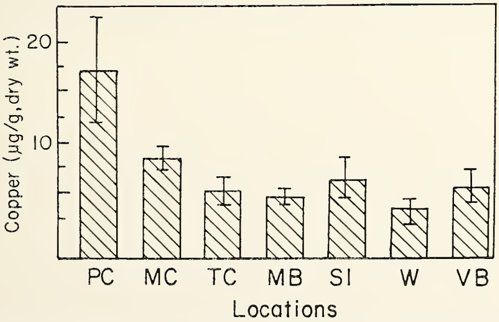

Fig. 6. Whole clam copper concentrations at selected Indian River sites and in the Port Canaveral Turning Basin. (PC = Port Canaveral, MC = Melbourne Causeway, TC = Turkey Creek, MB = Melbourne Beach, SI = Sebastian Inlet, W = Wabasso, and VB = Vero Beach).

g/da and that it produces up to 10 times higher Cu concentrations in water, suspended matter, sediment and barnacles collected near harbor marinas than outside the harbor proper. Even transient crabs sampled in the harbor showed indications of a doubling in gonadal tissue Cu levels.

Mass balance calculations for Cu in the Eau Gallie system support retention of 75% of the pollutant Cu within the harbor, with the remainder flushing out into the open estuary. The primary removal mechanism for Cu from harbor waters is via sorption on suspended particulates and subsequent sedimentation. An estimated 830 kg of pollutant Cu have been deposited in the Eau Gallie sediments to date.

The apparent limitation in Cu efflux from the harbor certainly contributes to the observed normal levels of Cu in water, suspended matter, sediment and barnacles collected in the open estuary, only about 1.5 km away from the harbor source. Surveys for Cu in selected Indian River water, sediment and clam samples from Vero Beach to Melbourne show no anomalous values.

Extrapolation of the Cu story to other metals is presently limited to zinc (Barber and Trefry, 1981). Similar Zn distributions in Eau Gallie harbor barnacles point to a non-point source of Zn from galvanized metals, sacrificial anodes and similar Zn-laden materials.

With respect to Cu, the barnacles and crabs of the Eau Gallie Harbor have a higher than normal Cu body burden, yet one which is below some of the more extreme values reported in the literature. The order-of-magnitude elevations in water, suspended matter, and sediment Cu for the restricted harbor waters do evoke concern; especially when Cu is one of many potential pollutants released to the harbor. To solve such pollutant problems, regulations must be placed on the siting of marinas and the discharge of effluents to restricted embayments of the Indian River.

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Walter K. Taylor
Henry O. Whittier

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INSTRUCTIONS TO AUTHORS

Individuals who publish in the *Florida Scientist* must be active members in the Florida Academy of Sciences.

Submit a typewritten original and one copy of the text, illustrations, and tables. All typewritten material—including the abstract, literature citations, footnotes, tables, and figure legends—shall be double-spaced. Use one side of 8 ½ × 11 inch (21 ½ cm × 28 cm) good quality bond paper for the original; the copy may be xeroxed. Margins should be at least 3 cm all around. Number the pages through the Literature Cited section. Avoid footnotes and do not use mimeo, slick, erasable, or ruled paper. Use metric units for all measurements. Assistance with production costs will be negotiated directly with authors of papers which exceed 10 printed pages of text. *Excess over 10 pages by an author in a single volume will result in charges for additional pages.*

ADDRESS follows the author's name.

ABSTRACT—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

ACKNOWLEDGMENTS are given in the body of the text preceding immediately the Literature Cited section.

LITERATURE CITED section follows the text. Double-space every line and follow the format in the current issue.

MANUSCRIPTS of 5 or less, double-spaced typewritten pages should conform to the short article protocol. See recent issue for proper format of both long and short articles.

TABLES shall be typed on separate sheets of paper, double-spaced throughout. Each table shall contain a short heading. Do not use vertical rulings. Maximum character width, including spaces, of tables is 98.0. This includes a minimum space of 5 characters between columns. Tables are charged to authors at $30.00 per page or fraction.

ILLUSTRATIONS—All drawings shall be done in good quality India ink, on good board or drafting paper. Letter by using a lettering guide or equivalent. Typewritten letters on illustrations are unacceptable. Drawings and photographs should be large enough to allow 1/3 to 1/2 reduction in size. Photographs shall be glossy prints of good contrast. Whenever possible, mount photographs in lots size.

The author's name and figure number should be penciled lightly on the back of each figure. Figure legends must be listed on a separate page and *not* on the drawing or photograph. The legend must be double-spaced. Illustrations are charged to authors at $25.00 per page or fraction.

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Volume 46 Supplement 1

Program Issue

THE FORTY-SEVENTH ANNUAL MEETING OF THE ACADEMY

in conjunction with the
FLORIDA JUNIOR ACADEMY OF SCIENCES
FLORIDA SCIENCE TALENT SEARCH
FLORIDA SECTION, AMERICAN ASSOCIATION OF PHYSICS TEACHERS

featuring the 1982 F.A.S. Medalist Address
"THE FASCINATING WORLD OF LARGE MOLECULES"
by GEORGE B. BUTLER
University of Florida

a Special Plenary Address
"OUR HERITAGE AND OUR FUTURE"
by HANS MARK, Deputy Administrator
NASA

and a Symposium
"USES OF ANTHROPOLOGY IN LAW, BUSINESS, AGRICULTURE, RESOURCE MANAGEMENT, AND COMMUNITY DEVELOPMENT"
organized by LESLIE S. LIEBERMAN, Chair
Anthropological Sciences Section

FLORIDA INSTITUTE OF TECHNOLOGY
Melbourne, Florida

7 to 9 APRIL

1983

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES
PROGRAM ISSUE PRICE $2.00

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1982-1983

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FORTY-SEVENTH ANNUAL MEETING OF THE FLORIDA ACADEMY OF SCIENCES

at

FLORIDA INSTITUTE OF TECHNOLOGY, MELBOURNE

7 to 9 April 1983

All registrants for meetings of the Senior and Junior Academy and the Florida Section of the American Association of Physics Teachers are welcome to attend all sessions of all organizations.

Florida Institute of Technology

The main campus of Florida Institute of Technology, a private university founded in 1958, is located in Melbourne on the central east coast of Florida. The center of campus lies on University Boulevard between Babcock Street and Country Club Road. Melbourne can be reached on US Rte. 192 (New Haven Avenue) via Interstate 95 by travellers from north and south Florida and Interstate 4 by travellers from central Florida and the Gulf coast. Commercial air service is available to Melbourne Regional Airport. Refer to the maps on the outside and inside back cover.

Registration

Registration is required for all attendees. A registration desk will be operated on the deck of the Donald L. Shephard Seminar Building from 8:00 am to 4:00 pm on Friday, 8 April, and from 8:00 am to 3:00 pm on Saturday, 9 April.

The registration fee is $5.00 for members, $7.00 for non-members, and $3.00 for students. Members receive the Florida Scientist Program Issue by mail, as will others registered by 1 March. A late registration fee of $2.00 will be assessed members and non-members (students excepted) registering after 1 March. Extra programs cost $2.00.

Lodging

No reservations can be made through the Academy. The following motels are a selection of major chains serving the Melbourne area. Rates in some cases are current commercial rates and cannot be guaranteed. Except where indicated, add about $5.00 per person to the single rate for multiple occupancy. Please make reservations as soon as possible, and identify yourself as an FAS participant. The general locations of the motels are indicated by asterisks (*) on the map.

Days Inn, 4455 W. New Haven Ave., Melbourne 32901. 305-724-5840. $22, up to 4/rm. Contact Clare Hughes. 6 mi from FIT.

Holiday Inn Melbourne Midtown, 440 S. Harbor City Blvd., Melbourne 32901. 305-723-3661. $30 single. 4.6 mi from FIT.

Holiday Inn Melbourne Oceanfront, PO Box 3775, Indialantic 32903. 305-777-4100. $49, up to 4/rm. 7.2 mi from FIT.

Holiday Inn Melbourne West, 4500 W. New Haven Ave., Melbourne 32901. 305-724-2050. $32-37 single. 6 mi from FIT.

Host of America, 420 S. Harbor City Blvd., Melbourne 32901. 305-723-5320. $25 single. Contact Betty Sheets. 4.7 mi from FIT.

Ramada Inn, 964 S. Harbor City Blvd., Melbourne 32901. 305-724-4422. $35 single. contact Sally Curry. 3.8 mi from FIT.

Banquet and Food Service

The banquet will be held on Friday evening, 8 April. The 1982 Medalist address by Dr. Butler will immediately follow. Dinner (roast top round of beef) will be served at Holiday Inn Melbourne Oceanfront, located surfside on the Atlantic Ocean (see map) and featuring Mr. Tease Nightclub and a poolside lounge. Contact Joyce Powers at the Academy office (305-896-7151) to purchase tickets ($12, limited availability after 30 March at $13).

Information about nearby food services will be available at the registration desk. Facilities on campus include two cafeterias, serving breakfast, lunch, and dinner.

Stand-Ins and Cancellations

If the author or a coauthor of a scheduled paper cannot present the paper due to illness, unforseen conflict, or other circumstance, the author should arrange for a colleague to read the abstracted paper. If a reader cannot be enlisted, the paper should be cancelled. The Academy should be notified about a reader or an intent to cancel. Early notification will allow inclusion of the change in a program supplement and will spare the author of a cancelled paper the embarrassment of an apparent no-show.

Contact (in preferred order) R.L. Turner, Program Chair (305-723-3701, ext 262), Joyce Powers at the Academy office (305-896-7151), the section chair, or the presider of the session.

Field Trips and Tours

Modern Industrial Research and Processing Facilities. In the shadow of the nation's spaceport, several Melbourne companies occupy forefront positions in the high-technology information processing industry. Two tours have been arranged for mid-afternoon of Friday, 8 April. Please make reservations through James R. Sharber (F.I.T.) at 305-723-3701, ext. 325 by 7 April or at the registration desk on 8 April. Both tours have a limited capacity. Participants will meet at the designated time at the registration desk and will be led by an F.I.T. representative. Participants may be requested to assist in providing transportation.

Tour 1 is through the research and processing facilities of Harris Corporation, a company which does basic research and engineering in information processing and storage, ground and satellite communications systems, and production and use of state-of-the-art semiconductor devices. Limit 25 persons. 2:30 pm.

Tour 2 is through the production and fabrication facility of STC/Documation, a producer of very high-speed printers. The tour will include a view of the largest machine shop in Central Florida, observation of printer fabrication, and a demonstration of high-speed printing capability. Limit 20 persons. 3:00 pm.

Sebastian Inlet State Recreation Area. Florida's most heavily visited state park contains several subtropical marine and terrestrial communities of biological interest, including rock-jetty, mangrove, intertidal sand-flat, maritime dunes, and high energy beach. A walking tour of these communities will take about 4 hr, including travel time. Please wear sneakers or other wettable foot-gear, and dress according to local weather conditions. Collecting of specimens in the park is not permitted. Participants will meet at the registration desk at 8:30 am, Saturday, 9 April. The field trip will be led by Kerry B. Clark, Biological Sciences, F.I.T. Participants may be requested to assist in providing transportation.

Kennedy Space Center. Round-trip bus transportation between F.I.T. and K.S.C. will be provided for up to 50 persons on Saturday afternoon at a cost of $1.00 each. In addition to a new gift shop, the visitor center also provides about 2 hr of museum displays and public lectures on various topics in the space sciences at no charge. For those wanting the 2-hr guided bus tour of the launch and support facilities at 3:00 pm, the tour fee will be an additional $3.00 each. Reservations must be made and fees paid at the registration desk. Participants will meet with the F.I.T. representative in the gymnasium parking lot (see map) at 1:15 pm for boarding. The bus will depart K.S.C. upon conclusion of the guided tour (about 5:00 pm).

Announcements

Computer Sciences and Mathematics Section. This new section of the Academy was established at the last meeting of the FAS Council. It is presently chaired by Pan Papacosta of Stetson University and has a full half-day session of contributed papers this year.

Council Meeting. There will be a meeting of the FAS Council at 7:00 pm, Thursday, 7 April, in Black 1 of the Donald L. Shephard Seminar Building. All section chairs and chairs-elect as well as other members of the Council should attend.

Florida Junior Academy of Sciences and Science Talent Search. Members of the Senior Academy are needed as judges and interviewers on Friday and Saturday. If you would be willing to serve, please contact Dorothy Henley, Cardinal Gibbons High School, 4520 N.E. Terrace, Ft. Lauderdale 33334 (305-772-4836, after 3:00 pm) or the Academy office (305-896-7151).

Smoking. Florida Institute of Technology policy prohibits smoking in lecture halls and laboratories.

Acknowledgments. The Program Chair appreciates the technical assistance of Haydee A. Hernandez, Marjorie B. Richardson and Pamela G. Smith in preparation of the program issue. Duane E. DeFreese prepared both maps on the back cover.

PLENARY SESSIONS AND BANQUET

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
EDWIN F. STROTHER, Florida Institute of Technology, presiding

1:30 pm Welcoming Remarks. Dr. JEROME P. KEUPER, President, Florida Institute of Technology, Melbourne
1:35 pm Introduction. Dr. JAY BURNS, Head, Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne
1:40 pm Our Heritage and Our Future. Dr. HANS MARK, Deputy Administrator, National Aeronautics and Space Administration, Washington
2:10 pm BUSINESS MEETING: The Florida Academy of Sciences

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
EDWIN F. STROTHER, Florida Institute of Technology, presiding

6:30 pm	Cocktails (cash bar)
7:30 pm	Banquet (meat dish of roast top round of beef)
8:30 pm	The Fascinating World of Large Molecules. Dr. GEORGE B. BUTLER, 1982 FAS Medalist, University of Florida, Gainesville
9:30 pm	Presentation of the 1983 FAS Medalist Award. Dr. HAROLD J. HUMM, 1981 FAS Medalist, University of South Florida, St. Petersburg

PROGRAM SUMMARY

THURSDAY EVENING, 7 APRIL 1983

7:00 pm	Council Meeting	Black 1

FRIDAY MORNING, 8 APRIL 1983

8:00 am	REGISTRATION (to 4:00 pm)	Deck
8:15 am	Biological Sciences A	Gold 1
	Computer Sciences and Mathematics*	Black 2
8:30 am	Geology and Hydrology A*	Red 1
	Medical Sciences*	Gold 2
9:00 am	Anthropological Sciences A**	Black 1
9:30 am	Agricultural Science A*	Red 2

FRIDAY AFTERNOON, 8 APRIL 1983

1:30 pm	PLENARY SESSION I	Aud
2:30 pm	Geology and Hydrology B	Red 1
	Urban and Regional Planning*	Black 2
	Harris Corporation Tour	Deck
2:45 pm	Agricultural Sciences B	Red 2
	Biological Sciences B	Gold 1
3:00 pm	Anthropological Sciences B	Black 1
	STC/Documation Tour	Deck

FRIDAY EVENING, 8 APRIL 1983

6:30 pm	BANQUET and PLENARY SESSION II	Inn

SATURDAY MORNING, 9 APRIL 1983

8:00 am	REGISTRATION (to 3:00 pm)	Deck
8:15 am	Biological Sciences C*	Gold 1
	Engineering*	Black 1
8:30 am	American Association of Physics Teachers, Florida Section*	Red 2
	Sebastian Inlet Field Trip	Deck
9:00 am	SYMPOSIUM: Anthropological Sciences	S-112
	Physical, Atmospheric, Oceanographic, and Space Sciences A*	Red 1
	Social Sciences*	Black 2

SATURDAY AFTERNOON, 9 APRIL 1983

1:15 pm	Biological Sciences D	Gold 1
	Environmental Chemistry A*	Red 2
	Science Teaching*	Black 2
	Kennedy Space Center Tour	Gym
1:30 pm	Anthropological Sciences C*	Black 1
	Physical, Atmospheric, Oceanographic, and Space Sciences B	Red 1
2:15 pm	Florida Committee on Rare and Endangered Plants and Animals*	Gold 2
3:00 pm	Environmental Chemistry B	Red 2

*Business meeting follows **Awards committee meeting follows

ABBREVIATIONS: Rooms in the Donald L. Shephard Seminar Building are designated by color and number, and the deck will be used for registration and other activities; W. Lansing Gleason Auditorium, Aud; Crawford Science Building, S-112; gymnasium parking lot, gym; Holiday Inn Melbourne Oceanfront, Inn.

AGRICULTURAL SCIENCE

FRIDAY 9:30 am Donald R. Shephard Seminar Building, Red 2
SESSION A: Cropping Management and Tropical Fish
J.M. BENNETT, University of Florida, presiding

9:30 am AGR-1 Influence of Level of Technology on the Cropping Systems. K. C. REDDI, G. M. PRINE, AND E. C. FRENCH, Agronomy Department, University of Florida, Gainesville 32611. Several intercropping systems were evaluated for their productivity under low and high inputs (N and water) supply in two separate sets of experiments in the Semi-Arid Tropics (SAT) of India. Exp't. 1: Mungbean (*Vigna radiata* (l.) Wilczek)/sorghum (*Sorghum bicolor* (L.) Moench), and pigeonpea (*Cajanus cajan* (L.) Millsp)/sorghum systems intercropped under rain fed, low (0 kg N/ha) and high (40 and 80 kg N/ha) N regimes produced higher economic returns compared to their respective sole crops systems. Exp't. 2: Pearl millet (*Pennisetum americanum* (L.) Leeke)/peanut (*Arachis hypogaea* L.), pearl millet/sorghum, sorghum/peanut, and chickpea (*Cicer arietinum* L.)/safflower (*Carthamus tinctorius* L.) wystems were intercropped under low and optimum soil moisture regimes, in Alfisol and Vertisol soils. These intercropping systems produced significantly higher economic returns than their respective sole crop systems only under low moisture regimes in Alfisol soils.

9:45 am AGR-2 Importance of Water to Crop Production. G. F. Lorens and J. M. Bennett, Agronomy Dept., IFAS, UF, Gainesville, 32611. The increasing crop yields which have been observed in recent years in the U.S. have been partially dependent on ample supplies of irrigation water, especially in the more arid and semi-arid environments. However, during the past two decades, irrigated acreage has also increased rapidly in more humid regions. As certain geographical regions struggle with equitable allocations of water resources and concerns are expressed for conservation of water resources, the importance of water to agriculture deserves emphasis. Crop production is dependent on photosynthesis which is intrinsically accompanied by water loss through transpiration because of the regulating activity of stomata. For maximal photosynthesis to occur, stomata must remain open allowing water movement from leaves to the atmosphere. The effects of water stresses applied at various growth stages, water requirements for potential evapotranspiration, and irrigation water needs of several agronomic crops grown in Florida will be discussed with emphasis placed on efficient use of irrigation water.

10:00 am AGR-3 Water Relations of a Soybean Crop During its Growing Season. M.F. Ahmed, K.J. Boote, and J.M. Bennett, Agronomy Dept., IFAS, UF, Gainesville, FL, 32611. Bragg soybeans (*Glycine max* L. Merr.) were grown in lysimeters and irrigated at -0.1 bar soil water potential. Leaf water potential measurements, together with the leaf diffusive resistance measurements were taken at midday for plants at different growth stages. Osmotic potential began to decline at flowering stage, while leaf water potential slightly increased, resulting in increased turgor pressure (5 bars at V5 to 8 bars at R1). Henceforth, osmotic and water potentials declined in parallel during the reproductive period until late seed fill, while turgor pressure remained relatively the same. Transpiration rates abruptly dropped beginning at the seed-filling stage (45 at flowering to 20 mg H_2O cm^{-2} at seed-filling). Diffusive resistance remained almost constant up to R6, then increased to the end of the season.

10:15 am AGR-4 Effect of Length of Fall Grazing Period on Seed Production of Aeschynomene Americana. W. D. PITMAN AND R. S. KALMBACHER. UF, ARC, Ona 33865. Aeschynomene (*Aeschynomene americana* L.) is a high quality summer annual legume adapted to the flatwoods soils of Peninsular Florida. Excellent stands are commonly obtained in the year of seeding with gradual declines in plant populations from natural reseeding in succeeding years. Twelve 0.16 ha paddocks were planted to aeschynomene in 1981 and grazed with yearling steers to evaluate the effect of length of the fall grazing period on aeschynomene seed production. Padocks were assigned to three treatments or termination dates for grazing with four replications of each treatment in a randomized complete block design. Seed yields averaged 12.8, 17.7, and 27.7 g/m^2 for paddocks grazed until 4 Nov. (When plant growth had ceased), 8 Oct. (When flowering began), and 2 Sept., respectively. Standing herbage on 1 Dec. revealed that ungrazed growth was 84, 153, and 493 g/m^2 when grazing was terminated on 4 Nov., 8 Oct., and 2 Sept., respectively. Aeschynomene growth in spring of 1982 was more dense with reduced fall grazing.

10:30 am BREAK

10:45 am AGR-5 The Florida Tropical Fish Triangle. D. M. STOWERS AND MICHAL L. LEVASSEUR, University of South Florida, Department of Geography, Tampa, FL 33620. The collecting of tropical fish is now the second most popular hobby in the United States. During the early years of the hobby most tropical fish were imported; however, today the breeding of fish is primarily located in a small triangular region in west central Florida. The location of the industry in this area was primarily due to: (1) convenient air transportation and (2) climate, soils and water supply. Several farms will be discussed to illustrate the layout and the operation of the farms, as well as the preparation and shipment of fish. The Florida industry today faces not only an increased cost of production coupled with a devaluation in the price of its product, but serious competition from an Asian industry. In 1957, the Florida Tropical Fish Farmers Association, Inc. was formed to combat the increasing Asian imports and to promote Florida's little known industry. The organization is also active in the development of a plan for new programs to aid aqua-culture in the state of Florida.

11:00 am AGR-6 Influence of Tillage on the Accumulation and Partitioning of Dry Matter and Energy in a Rye/Soybean Double-Cropping System. T. J. POST AND R. N. GALLAHER, Agronomy Department, University of Florida, Gainesville, 32611. No-tillage (NT) small grain /soybean (Glycine max L. Merr.) double-cropping management is widely used in the southeastern United States. This study compared the dry matter (DM) and combustible energy (CE) production of rye (Secale cereale L.) and soybean, as influenced by tillage. Tillage, after 4 years of NT, tended to increase DM and CE accumulation by rye and soybean. Most rye and soybean plant parts showed greater accumulation of DM and CE in 15-cm till plots than in continuous NT plots. Subsoiling tended to increase production of DM and CE in rye, but not in soybean. For rye, 26% of the final DM was grain, with 53, 15, and 5% in stems, leaves, and roots, respectively. Averages for soybean showed 29% of final DM was seed, 25% stems, 28% leaves, 13% pod walls, and 5% roots. In this double-cropping system, 19.7 million kcal CE/ha was harvested in grain and/or seed while 42.1 million kcal CE/ha was returned to the soil in crop residues.

11:15 am AGR-7 Weeds in Conventional vs. No-tillage Peanuts. S. R. COSTELLO AND R. N. GALLAHER, Agronomy Department, University of Florida, Gainesville 32611. The Florida peanut (Arachis hypogea, L.) crop is often subjected to intensive wind and water erosion that results in soil, fertilizer, and pesticide losses. Physical damage to the peanut can also reduce yields. The objective of this study was to evaluate the influence of small grain residue on no-tillage and conventional tillage peanuts, with particular attention given to weed populations. No-tillage mulched and un-mulched (rye, Secale cereale L., straw either retained or removed prior to planting) peanuts were compared to conventional tillage peanuts with mulch incorporated or removed prior to tillage. Weed counts were taken at regular intervals before and after chemical herbicides were applied. Significantly fewer weeds were found in no-tillage plots for one year, but not for the succeeding year. The no-tillage plots generally had significantly fewer broad leaf weeds, but an equal number of grasses. A trend for reduced peanut yields in the mulched plots was not continued in the second year.

FRIDAY 11:30 am Donald R. Shephard Seminar Building, Red 2
BUSINESS MEETING: Agricultural Science Section
R. N. GALLAHER, University of Florida, presiding

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 2:45 pm Donald R. Shephard Seminar Building, Red 2
SESSION B: Cropping Management and Economics, Soil Fertility, and Plant Nutrition
K.L. BUHR, University of Florida, presiding

2:45 pm AGR-8 An Economic Comparison of Monocropping and Double Cropping Some Row Crops Under Conventional and Minimum Tillage in Georgia, Using Linear Programming. LUGABA C. RUHIMBASA AND P. J. VAN BLOKLAND, Food and Resource Economics Department, University of Florida, Gainesville, Florida, 32611. An economic analysis was completed of 18 monocropping and 40 sequential double cropping systems using wheat and barley as the winter crops and corn, sorghum and soybeans for grain and forage (except soybeans for forage) as summer crops. The data came from agronomic trials in Georgia, budget information from Florida and Georgia. These data were used to select the best system or combination of systems for increasing net farm income per acre against land, labour and capital constraints in a linear programming model.

3:00 pm AGR-9 Tillage and Metribuzin Management Affecting Weed Competition for Dry Matter and Nitrogen Accumulation in Soybean. S. DYAL AND R. N. GALLAHER. Agronomy Department, University of Florida, Gainesville 32611. Weeds are the biggest pest that cause reduced soybean (Glycine max L. Merr.) yields in Florida. The objective of this study was to determine the competition between weeds and soybean as affected by tillage (straw incorporated or removed before incorporation) and rate of metribuzin (lexone) (4-amino-6-tert-butyl-3-(methyl-thio)-as triazine-5(4H)-one) herbicide. In General tillage treatment did not affect dry matter production of either soybeans or weeds. Soybean dry matter yield was reduced at low rates of herbicide and generally increased up to the 0.56 kg/ha rate based on two year averages. The dominant weed was sicklepod (Cassia obtusifolia L.) which decreased as herbicide rates increased. Application of herbicide caused N concentration to increase in soybean and decrease in weeds. The N decrease in weeds was due to stunted plants and limited growth caused by herbicide injury. At harvest soybeans contained 84% of the total N produced and weeds 16%.

3:15 pm AGR-10 Effect of Multicropping, No-Tillage, and Nitrogen on Grain Sorghum. VAL J. EYLANDS AND RAYMOND N. GALLAHER, Agronomy Department, University of Florida, Gainesville, 32611. Grain sorghum (Sorghum bicolor L. Moench, Dekalb "BR 64") following some winter forage crops may achieve optimum yields with low levels of applied N. The objective of this 2 year study was to evaluate grain sorghum planted after winter green manure crops of rye (Secale cereale L.) or lupine (Lupinus albus) or into Pensacola bahiagrass (Paspalum notatum Flugge) or into fallow areas with varying levels of N fertilizer. After harvesting winter forages, grain sorghum was planted no-tillage into stubble or fallow or into conventional tillage seedbeds. Grain sorghum yields were lower when planted no-tillage into Pensacola bahiagrass as compared to other plots. Grain yields reached a maximum with 56 kg N/ha whereas whole plant dry matter yields responded to 112 kg N/ha. Total N uptake and crude protein yield increased as N fertilizer increased.

3:30 pm AGR-11 The Cycling of Residual N and P in a Rye/Soybean Double-Cropping System as Affected by No-Tillage. R.N. GALLAHER AND T.J. POST, Agronomy Department, University of Florida, Gainesville 32611. No-tillage (NT), small grain/soybean (Glycine max. L.) double-cropping is increasing in the southeastern United States. This study compared the effect of NT versus 15-cm tillage, and subsoiling versus nonsubsoiling on organic matter (OM), N, and P in the soil and on plant uptake of N and P. Rye (Secale cereale L.) was followed by soybean. Subsoiling increased soil OM and extractable P and reduced N in the 0- to 30-cm layer as compared to nonsubsoiling. Subsoiling had little effect on N accumulation by rye; but tended to reduce N accumulation by soybean; and increased P accumulation in both rye and soybean. Fluctuations observed in total N and extractable P contents in the 0- to 30-cm soil layer indicate that recycling of N and P from crop residues to the soil occured. Under rye/soybean double-cropping management the quantity of extractable P in the 0- to 30-cm soil layer was observed to have increased during the year of the study.

3:45 pm BREAK

4:00 pm AGR-12 Effect of Nitrogen Fertilization on Yield and Nitrogen Distribution in Peanut (Arachis hypogaea L.). AHMAD SELAMAT AND F.P. GARDNER, Agronomy Dept., Univ. of Fl., Gainesville, 32611. Field and pot experiments were conducted in 1982 to investigate the effects of N levels on nodulating and non-nodulating lines; Early Bunch (EB), Florunner (FL) and non-nodulating strain (NN). Field N rates were 0, 60, 120, and 240 kg/ha. Pot N rates were 0.05, 0.50, 0.95, and 1.40 Hoagland's solution at 0.50 strength of other nutrients. Pod yield in the field from the NN increased linearly (1.0 to 2.7 t/ha) with N rates. Pod yield of FL (nodulating) was greatest at 0 kg N/ha (3.5 t/ha) and EB peaked at 60 kg N/ha (3.4 t/ha). The total dry weight (TDW) of NN steadily increased over the entire range. EB responded up to 60 kg N/ha. The TDW of FL was not affected by N application. In the pot experiment, pod yields of FL and NN increased similarly and linearly over 0.05 to 0.95 Hoagland's solution strength and slightly dropped beyond 0.95 level, EB slightly increased over all rates. The uptake, concentration, and partitioning of N are discussed in relation to pod yields.

4:15 pm AGR-13 Nitrogen Mineralization from Soil Incorporated ^{15}N-Labelled Water-hyacinth. R. A. OGWADA, K. R. REDDY AND D. A. GRAETZ, Univ. of Florida, Sanford 32771. The potential of N-mineralization from soil incroporated water-hyacinth (Eichhornia crassipes) was studied in a greenhouse for 60 days. ^{15}N-labelled water-hyacinth (20 mt/ha) was incorporated into Myakka fine sand (Aeric Haplaquods) and incubated for 2 weeks before planting. The treatments used in the study included control, fertilizer only (100 kg N/ha), water-hyacinth only (240 org. ^{15}N/ha), water-hyacinth + fertilizer (240 kg org. ^{15}N + 50 kg N/ha). Sorghum-sudangrass hybrid (Sorghum sudanense) was used as a test crop. At the end of 60 day study period, about 62 to 67% of the hyacinth ^{15}N remained in the soil as organic N, 0.8 to 1.6% as inorganic N, 13 to 20% was recovered by the sorghum plants, while about 12 to 24% was lost from the system. The soil-incorporated water-hyacinth enhanced the mineralization of native soil organic N. Addition of fertilizer N increased mineralization from both soil-incorporated hyacinth and native soil organic N. Water-hyacinth addition significantly increased the biomass yields of sorghum-sudangrass hybrid.

4:30 pm AGR-14 Potassium Fertilization for Cabbage, Sweetcorn, and Soybeans in a Multiple Cropping Sequence. R. B. FORBES, J. B. SARTAIN, AND N. R. USHERWOOD, Univ. of Florida, Agricultural Research and Education Center, Sanford 32771, Soil Science Dept., Gainesville 32611, and Potash/Phosphate Inst., 1649 Tullie Circle, N. E., Atlanta, GA 30329. Field studies were begun in June 1981 with soybeans, followed by cabbage and sweet corn to determine optimum K rates and scheduling for the three crops each year grown in succession on the same land at Sanford on Immokalee fine sand. All three crops have now completed a year's cycle plus a 1982 summer crop of soybeans. Sufficient residual K (66 ppm avg.) was present for the first crop of soybeans and the cabbage which followed. Sweetcorn, the third crop on the same plots, showed an increase from K fertilization and severe deficiency symptoms where K was omitted with soil K levels as low as 10-20 ppm. Soybeans in 1982 gave a 672 kg/ha increase where K was applied to the soybeans or where 200-400 kg/ha applications of K had been made to previous crops. Analyses of soils and plant tissue reflected effects of the K treatments.

4:45 pm AGR-15 Chemical Analyses of a Wild Legume Species With Twofold Reproductive Capabilities. K. L. BUHR, AND R. N. GALLAHER, Agronomy Department, University of Florida, Gainesville, 32611. The wild legume Amphicarpa bracteata L. Rich. & Staf. has been observed to be a preferred plant for grazing by farm animals. The fact that this plant reproduces by underground apetalous reproductive organs, as well as above ground seed pods, suggests that it may have survival potential under conditions of intense grazing pressure. A comparison of the laboratory chemical analyses of this wild legume, known as "wild pea" or "hog peanut", with several cultivated plant species reveal component similarities with cultivated peanut, Arachis hypogaea.

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

AMERICAN ASSOCIATION OF PHYSICS TEACHERS, FLORIDA SECTION

SATURDAY 8:30 am Donald R. Shephard Seminar Building, Red 2
J.A. MEYERS, University of Central Florida, presiding

8:30 am APT-16 Does the Proton Decay? Jack H. Noon, University of Central Florida. Over the last decade technological advances in equipment have made possible experiments to test the absolute validity of what we usually teach as well established assumptions to our undergraduates. Typical heretical conjectures presently being tested experimentally include: does the gravitational constant change with time? does the indeterminicy principle limit quantum measurements absolutely? is the electronic charge really the smallest unit? is causality real i.e. can a delayed choice of observation technique cause a change in the result obtained from an experiment in progress? This paper focuses on one of these conjectures and reviewed work being carried out by a number of laboratories to establish whether the proton is or is not stable. The theoretical significance of the question of proton stability is considered and a list of references supplied.

8:45 am APT-17 The Simple Machine Laboratory on the Computer. Patricia Olgarden, Seminole Community College. A computer program has been written for the Apple Computer which gives the procedures to the students for doing the Simple Machine laboratory. It will then do the calculations for them when they put in their data and check their results. These calculations will be printed out so they have hard copy of their work. This program will be demonstrated and several of the difficulties in writing it will be discussed.

9:00 am APT-18 The Recent New York Annual Meeting of AAPT. Alexander K. Dickison, Seminole Community College. Highlights are presented of the joint annual AAPT-APS meeting in New York, January 23-27, 1983. Special attention is given to items of interest to members of the regional sections.

9:15 am APT-19 Teaching Physics to the Older Student. ROBERT G. CARSON, Rollins College. Despite the record numbers of young people going to college today, there are many older people starting or returning to college. The vast majority of them will major in non-scientific fields but they are still curious and a bit apprehensive about science (especially physics). One of the requirements for a bachelor's degree in our Division of Continuing Education is the completion of two science courses with associated lab experiences. I have recently developed and taught a course in contemporary physics to introduce these students to some of the topics they find discussed in newspapers and popular science magazines as well as on television. An excursion through classical physics, complemented with five "mini-labs", helps to provide them with a base of reference when we discuss some of the modern physics topics. An outline of the course, the particular problems encountered by older students, and the need for similar courses in the sciences will be discussed.

9:30 am APT-20 A New Experience in Teaching Physics to Non-physicists. STANLEY S. BALLARD, University of Florida. Last semester I taught a special general physics course under a state-wide grant from the State Department of Education to strengthen the mathematics and science skills of public school teachers. The class numbered 13: 8 high school teachers and 5 middle school teachers. Only 3 of the 13 were currently teaching (high school) physics; only 6 of the teachers had studied some physics in college. The problem of teaching introductory physics to such an inhomogeneous group should be obvious, despite their maturity and the motivation that they exhibited. The textbook selected was ideal for the situation: Conceptual Physics, by Paul G. Hewitt (Little, Brown; 4th ed., 1981). A less fortunate, more mathematical textbook choice would have been disastrous! Of special interest were the demonstrations that were shown during almost every 3-hour weekly class period. But how does one decide on final course grades? Scores on subject-matter quizzes and exams are not fair to those with zero physics preparation or experience. So what to do?

9:45 am BREAK

10:00 am APT 21 Interfacing the VIC-20 Microcomputer to Introductory Physics Experiments. E. RONALD KIRKLAND, Department of Physics, University of Central Florida, Orlando, Florida 32816. The inexpensive yet versital VIC-20 has four ports through which it may be interfaced to experiments. It also has high resolution graphics. Data acquisition with the manipulation of data (i.e., graphing) will be described and demonstrated. Necessary hardware and software will be detailed for three of the ports.

10:15 am APT-22 Thermal Expansion Measurements from 70 to 525K. James Steve Browder and Kristian P. Biggs, Jacksonville University; and Stanley S. Ballard, University of Florida. We report the most recent measurements of optical materials[1], including KCl (europium doped) and $Bi_4Ge_3O_{12}$ (bismuth germanate, BGO). The coefficients of linear thermal expansion were determined by using two high resulution capacitance dilatometers, one for the temperature range 70K to room temperature and the other for the range from room temperature to about 525K. The samples were kindly supplied by the Harshaw Chemical Company.

[1] Florida Scientist, Vol. 38, Supplement 1, 1975, p. 28.

10:30 am APT-23 Feigenbaum's Universality in Nonlinear Systems. Peter Rembiesa, University of Central Florida. Many physical systems achieve the turbulent behavior through the production of successive half subharmonics. Unexpectedly, the mechanism of transition from periodic to erratic behavior is universal for a vast class of very different systems. New universal constants and universal functions provide a qualitative description of periodic behavior almost independently of the system under consideration.

10:45 am APT-24 Supersymmetry and Renormalization: A Classical Analogy. Weldon Wilson, University of Central Florida. A classical Lagrangian is given which may be used to introduce physics majors to the concepts of supersymmetry and renormalization on the classical level. The model Lagrangian could be used in any junior-senior level mechanics course once the Lagrangian formulation of mechanics has been covered. The analogy with supergravity, supersymmetric field theories, and mass and charge renormalization is developed.

11:00 am APT-25 Radioactivity Levels in Coal Mine Wastes. Ralph A. Llewellyn, University of Central Florida. The relatively high cost of oil for electrical generation has made it economically attractive to consider using the wastes from coal cleaning plants as a fuel source. The wastes average approximately 9-10,000 Btu/lb, about the same as western sub-bitiminous coal, and are already finely divided making them candidates for slurry pipelines. However, a large portion of the potential environmental contaminants in the original coal seam end up in the cleaning plant wastes. This study assesses the extent to which natural radioisotopes may present a hazard if the cleaning plant wastes are burned in power plants.

SATURDAY 11:15 am Donald R. Shephard Seminar Building, Red 2
BUSINESS MEETING: American Association of Physics Teachers, Florida Section
B.H. LYND, Valencia Community College, presiding

ANTHROPOLOGICAL SCIENCES

FRIDAY 9:00 am Donald R. Shephard Seminar Building, Black 1
SPECIAL SESSION A: Ethnography of Games: Games of Ethnography
J.J. SMITH, University of South Florida, presiding

9:00 am ANS-26 Ethnography of Games: Games of Ethnography. J. JEROME SMITH, Department of Anthropology, University of South Florida. This presentation will introduce and summarize the special session of the same name. Our program is dedicated to the late James P. Spradley, whose pioneering work in ethnographic field work methodology and analysis serves as the framework of the papers abstracted below. A Model for ethnographic interviewing will be reviewed and the heuristic and substantive benefits of work in the arena of small board and card games will be outlined.

9:15 am ANS-27 The Joys of Euchre. ELIZABETH A. HORVATH, Department of Anthropology, University of South Florida. The use of games to explore methods of ethnographic research is heuristically beneficial in that a game may be considered as a closed system of cultural rules. The card game Euchre, played with two to seven participants will be discussed in detail from this perspective. Particular attention will be paid to the notion that game terminologies represent special opportunities for restrictive coding, to the extent of being a major dimension of the game itself.

9:30 am ANS-28 Seven-Card Stud: An Ethnography. ALEXANDRA PANZER, Department of Anthropology, University of South Florida. This paper seeks to demonstrate the use of ethnosemantic methods to elicit an emic, informant-based view of a particular cultural domain. In this case, one of the games of poker is explored. Primary emphasis will be placed on developing an account of the basic dimensions which characterize a particular game as Poker, by mapping out choices involved in betting procedures and other basic playing strategies.

9:45 am ANS-29 **Samba: An Afternoon's Delight. JEANNE P. HUNT, Univ. of South Florida, Dept. of Anthropology, Tampa, 33620. Spradley's ethnographic interview methodology was utilized to investigate the card game Samba. Formal and tacit rules were discovered and are described. Along with strategies of play they comprise the cultural knowledge required for competence in the game. The social significance of the game for players within its cultural time and place was investigated.**

10:00 am BREAK

10:15 am ANS-30 Backgammon: If You Win, You Get to Go to Heaven. CHRISTINE GEISER, Department of Anthropology, University of South Florida. This paper presents a formal ethnographic description of the popular board game of backgammon. Based on interviews with a single informant, an account of the rules and strategies of backgammon are developed. Viewed as a system of culturally shared knowledge, backgammon provides an opportunity to carefully examine relationships between rules, strategies, and behavior. Special attention will be paid to the use of "heaven" as a metaphor for winning.

10:30 am ANS-31 Scrabble: The American Way? DEBRA G. NIXON, University of South Florida, Department of Anthropology, Tampa 33620. The goal of ethnographic semantics is to discover and to describe the shared knowledge, the rules prescribing behavior, of a particular cultural group. This paper explores the knowledge shared by players of Scrabble, a popular board game. Formal methods of ethnographic analysis used to discover the categories of cultural knowledge are described. In addition to the explicit rules of the game, two particular domains in the realm of Scrabble players' knowledge shed light on the underlying complexities involved in play; these are the steps in taking a turn, and the characteristics of a good player. Parallels are drawn between the overt and covert rules of Scrabble and those inherent in the notion of the Protestant work ethic.

10:45 am ANS-32 A Formal Account of the Rules of Monopoly: MARCELLA CLAUDIA GUTIERREZ, Department of Anthropology, University of South Florida. Of the many methods of anthropological research, ethnographic interviewing is among the most important and potentially rewarding. A study of the popular board game of monopoly based on informant description of rules and strategies provides the materials necessary to develop a model of such a game that reveals the richness of underlying formal codes of play and conduct. The exercise also reveals several parallels between games as games and games as simulations of daily life.

11:00 am DISCUSSION

FRIDAY 11:30 am Donald R. Shephard Seminar Building, Black 1
MEETING: Anthropological Sciences Student Awards Committee
L.S. LIEBERMAN, University of Florida, presiding

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Academy of Sciences, presiding

FRIDAY 3:00 pm Donald R. Shephard Seminar Building, Black 1
SPECIAL SESSION B: Socio-Cultural Aspects of the Female Climacteric
B.M. DU TOIT, University of Florida, presiding

3:00 pm ANS-33 Status, Role, and the Climacteric. BRIAN M. DU TOIT, University of Florida, Dept. of Anthropology, Gainesville, FL 32611. Advancement through the life cycle is worked by changes in status and expected roles. The climateric is universally recognized as a phase when women have completed their reproductive role and enter a new phase of life. This new phase may be viewed positively or negatively depending on a number of cultural variables. The perspective here will be anthropological and cross-cultural.

3:15 pm ANS-34 Psychosocial Aspects of the Climacteric. JAQUELYN LISS RESNICK, University of Florida, Center for Climacteric Studies, Gainesville, FL 32611. This presentation will address the psychosocial aspects of menopause and the middle years. A brief historical perspective will be presented to consider the negative context of menopause and aging for women in American society. Psychological myths will be explored and recent research findings which contradict the myths will be presented. There will be a discussion of the climacteric as a normal development process affecting women. The author's clinical experience in interviewing several hundred climacteric women will be incorporated into the discussion of the current literature.

3:30 pm ANS-35 Age, Attitude, and Menopause. DAVID SUGGS, University of Florida, Center for Climacteric Studies, Gainesville, FL 32611. In an earlier publication, Neugarten and Kraines administered a questionnaire concerning menopausal attitudes to women between 21 and 65 years of age. Results showed significant differences in attitude by age. Since 20 years have passed that this research was done, a revised version of the Neugarten and Kraines scale has been administered to a sample of women between ages 21 and 65 in a southern city. The results are compared with those of Neugarten and Kraines' in order to look at attitude changes over this time period. Also, a scalogram analysis is conducted to determine whether the responses fit into the Guttman scale.

3:45 pm ANS-36 Sociocultural Characteristics as Risk Factors in Osteoporosis. MARSHA WARE, University of Florida, Center for Climacteric Studies, Gainesville, FL 32611. Osteoporosis is a complex, multifactorial disorder characterized by diminished bone mass and high risk of spontaneous fractures. Diet, ethnicity, the amount of physical activity, genetic factors, and environmental conditions all influence an individual's predisposition to osteoporosis. Because these characteristics vary from one sociocultural group to another it can be assumed that osteoporosis has a strong sociocultural component.

4:00 pm DISCUSSION

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 9:00 am Crawford Science Building, Room 112
SYMPOSIUM: Uses of Anthropology in Law, Business, Agriculture, Resource Management and Community Development
L.S. LIEBERMAN, University of Florida, presiding

9:00 am ANS-37 Applied Anthropology in the 1980's. LESLIE SUE LIEBERMAN, Department of Anthropology, University of Florida, Gainesville, FL 32611. During the last 50 years, anthropology has changed from a discipline involved in the classification of esoteric primitive customs to a holistic science of human biology, culture, and society. Within the last decade there has been the flowering of a field called applied anthropology. Although there is no major theoretical or methodological distinctions between "pure" and "applied" anthropology, the field of applied anthropology has two distinctive features. These are: (1) emphasis on problem-oriented studies of living peoples, and (2) application of research findings and analyses to fields outside anthropology. Often these applications affect policy decisions. This paper and the symposium explore the many areas in which applied anthropology is making contributions.

9:15 am ANS-38 Forensic Applications of Physical Anthropology. WILLIAM R. MAPLES, Florida State Museum, University of Florida, Gainesville 32611. One of the earliest and most common applications of anthropology is the use of physical anthropology in legal matters. Most frequently, such applications are the identification of human remains from skeletal evidence, first used by an anthropologist in the nineteenth century. Occasionally, it might involve some other legal issue, such as legal definitions of race or questions of paternity. This paper will discuss the history, present state, and future directions of the practice of forensic physical anthropology. Particular attention will be given to the diversity and the technical requirements of the present field.

9:45 am ANS-39 Business in Anthropological Perspective. JOHN F. SHERRY, JR., Marketing Department, University of Florida, Gainesville, FL 32611. In a belated response to the study of corporate business enterprises in industrial society, anthropologists as a group are returning to the business world as researchers and practitioners. A confluence of political and economic forces has catalyzed this renewed interest in the cultural environment of business. This paper examines the author's induction into the applied-academic business realm and discusses the areas of research appropriate to anthropological inquiry. Practical applications of the merger of anthropology and business are provided. The paper closes with suggestions for improving both the quality of entry level preparation for and academic research into the domain of business.

10:15 am ANS-40 Using Anthropological Tools to Understand Florida's Farming Systems and Small Farmers. ROBERT ZABAWA and CHRISTINA GLADWIN, Food and Resource Economics, University of Florida, Gainesville, FL 32611. Although farms in Florida have followed the national long-run trend of becoming fewer in number and bigger in size, small Florida farms in the 70's have managed to survive and even grow in number. How they are managing to survive in today's depressed economic environment is a question perplexing agricultural and social scientists. This paper shows how anthropological tools can be used to understand small farmers' survival strategies and traditional farming systems. It also illustrates the applicability of ethnographic research when a traditional way of life suddenly becomes nonadaptive and farmers have to change their farming system in order to survive.

10:45 am BREAK

11:00 am ANS-41 Cultural Resource Management and the Practical Applications of Archaeology. J. RAYMOND WILLIAMS, Department of Anthropology, University of South Florida, Tampa, Fl. 33620. As a result of local, state and federal historic preservation legislation passed since the 1960s, several hundred million dollars a year are spent on "cultural resource management." With large sums of public funds being expended, archaeologists must be able to explain the non-academic as well as the academic relevance of the discipline and must increasingly find ways to make the field more "practical." Unfortunately, this is complicated by the fact that archaeology has never been what the public perceives it to be. This paper attempts to summarize many of the non-traditional and rarely recognized applications of archaeology. Explanation of archaeology on this "level" will demonstrate the value of continued expenditures of public funds on cultural resource management.

11:30 am ANS-42 The Uses of Anthropology in Community Development. J. ANTHONY PAREDES, Florida State University, Department of Anthropology, Tallahassee, FL 32306. The uses of anthropology in community development are many and varied. They are classified as technical, analytical, and clinical. Application of anthropology to community development is largely reactive rather than prescriptive and requires awareness of the many-faceted meanings of the phrase "community development." Likewise, anthropologists must understand and monitor the interplay of autochthonous and exogenous elements in any particular case of community development. These points are illustrated with examples from the author's experience, especially his work with the Poarch Creek Indians of Alabama.

SATURDAY 1:30 pm Donald R. Shephard Seminar Building, Black 1
SESSION C: Medical Anthropology
B.E. ROTHSTEIN, Southeastern College of Osteopathic Medicine, presiding

1:30 pm ANS-43 Menarche -- Its Physiological and Cultural Significance. ANDREA JARDINE, Department of Anthropology,]350 GPA, University of Florida, Gainesville, 32611. Menarche is a physiological event in the maturation of women but, for many societies throughout the world, the advent of menarche has an important cultural function. I aim to briefly examine the physiological process culminating in menarche and then investigate how menarche is culturally recognised in various societies, attempting to find some explanation for individual versus group rituals.

1:45 pm ANS-44 A Physio-cross-cultural Model Concerning the Cathartic Process. GREGORY TOOTHMAN, Dept. of Anthropology, Florida State University, Tallahassee, FL 32303. Research was conducted along three avenues. First, biological data were assembled concerning recent neurological and biochemical research in order to establish a model of the cathartic process. Secondly, ethnographic data were gathered from the HRAF to look at the cultural and ceremonial basis of emotional release within a ritual context in various societies. Third, theoretical materials were correlated (including psychological and ethnological approaches) in order to establish a more comprehensive model of catharsis. This paper represents a summary of some of this material undertaken for completion of a master's thesis.

2:00 pm .ANS-45 The "Ethnic Factor" in Nurse-Patient Interaction. DEBORAH PADGETT, Florida Southern College, Lakeland, FL 33802. Medical practitioners often overlook the "ethnic factor" in treating patients. However, the fact remains that members of many ethnic groups have differing values and attitudes about health and illness, often complicated by language barriers. Such differences may seriously affect nurse-patient interaction. This paper summarizes the findings of a questionnaire given to 150 nurses in Polk County, Florida during a series of workshops on cultural diversity and nursing practice. Nurses' attitudes concerning cultural diversity and health care are described as well as their experiences as care providers for Southern Black, Haitian, and Hispanic patients. Factors which influence these attitudes such as family background and educational level are explored.

2:15 pm ANS-46 Doctors: Do They Show Their Patients What They Mean? BARBARA E. ROTHSTEIN, Southeastern College of Osteopathic Medicine, 1750 N.E. 168th Street, North Miami Beach, FL 33162. In recent years, the medical community has recognized that communication between physicians and their patients is an integral part of the health maintenance and healing processes. Communication involves both verbal and non-verbal communication. To better train physicians in the art of communication, specifically non-verbal communication, we have been studying the patients' perception of the nonverbal signals from doctors to their patients. In this paper we further investigate the perceptual differences of the physicians' non-verbal communications by various groups of patients.

SATURDAY 2:45 pm Donald R. Shephard Seminar Building, Black 1
SESSION D: Cultural Adaptations to Planned and Unplanned Change
J. HALL, University of Miami, presiding

2:45 pm ANS-47 Social Loafing in the United States and the Republic of China. WILLIAM K. GABRENYA, JR., School of Psychology, Florida Institute of Technology, Melbourne, 32901. Research conducted in the U.S. indicates that people exert greater effort in a variety of task situations when they perform individually than when they do so in a group that obscures identifiability of members' individual outputs, a phenomenon termed "social loafing." It was hypothesized that members of cultures whose value emphases and social institutions have been characterized as "group-oriented" would tend to form more cohesive groups and be more likely to place group benefit over individual benefit than members of individualistic U.S. culture, hence evidencing less social loafing. Contrary to this expectation, Chinese school children on Taiwan (grades 2 through 9), asked to produce sound by clapping and shouting alone and in pairs, evidenced levels of social loafing similar to those of a U.S. comparison group, suggesting the transcultural generality of this phenomenon for maximizing tasks. Limitations of the social restrictiveness of the sound production task for tapping cultural differences are discussed.

3:00 pm ANS-48 Adaptation and Transition of Some Traditions and Lifeways in the Isle of Lewis and Harris, Outer Hebrides, Scotland. BARBARA A. HENDRY, Dept. of Anthropology, Florida State University, Tallahassee, 32306. Fieldwork was conducted in the Isle of Lewis and Harris during ten months of 1981 and 1982. The island lies forty miles off the northwest Scottish mainland. The 15,000 islanders live in scattered coastal villages and are dependent on wage incomes and government subsidies to supplement meager profits from small crafts. The Isles are characterized by high unemployment and declining population due to emigration of the young. Local government authority was transferred to the islands in 1975 and new leaders, many returning native islanders, have made efforts to revive awareness of and pride in island traditions and the Gaelic language; and to promote community solidarity and economic opportunities. The adaptation and transition of traditions is helping the Hebrideans maintain distinct ethnic identity as well as contributing to local economic development and community survival.

3:15 pm ANS-49 Brief History of a Bi-racial Population in Alabama. F. DEANE CHAPMAN, Department of Anthropology, Florida State University, Tallahassee FL 32306. There are many multiracial populations in the southeastern United States that have remained distinct since before the Civil War. They are unique because as groups they have refused to bend to pressures from the dominant white population to affiliate themselves with the lower status black population. They have maintained an indeterminate social status. This paper details the history of one such group in Alabama. This group is the product of miscegenation during the French and Spanish Colonial period. It will be shown that the formation of this distinct population was the result of increased prejudice and resultant repressive laws towards free people of mixed ancestry prior to the Civil War.

3:30 pm ANS-50 A "Comprehensive" Model of Comprehensive Planning. DWIGHT L. SCHMIDT, Dept. of Anthropology, 1350 GPA, University of Florida, Gainesville 32611. Comprehensive planning increasingly is gaining attention among planners, legislators and the general public as states adopt legislation mandating that it be done. This type of planning has significant implications for communities and their resource-use decisions. This paper examines what is meant by comprehensive planning, and presents a broad, systemic perspective as to how it operates. Models depicting the structural elements and procedural (goal and evaluation defining) stages involved in such a planning mode are discussed.

3:45 pm ANS-51 Preliminary Investigation of Glauber Biggers BISC-UW 22 Site, a mid-Eighteenth Century Shipwreck in Biscayne Bay. JOHN E. HALL, Department of Anthropology, University of Miami, Coral Gables 33124. Following the accidental discovery in April, 1982, of a portion (c. 15 meters) of a larger hull, burned to the water line and submerged in shallow (2 meters at high tide) water near Soldier Key in Biscayne Bay, an underwater survey was undertaken to determine the approximate date, nationality, and possible historical significance of the vessel. Unusually well preserved ship's timbers, conglomerate containing various iron materials, nails, glass, slate, ballast stones of three types, and bricks were analyzed and tentatively dated.

SATURDAY 4:00 pm Donald R. Shephard Seminar Building, Black 1
BUSINESS MEETING: Anthropological Sciences Section
L.S. LIEBERMAN, University of Florida, presiding

BIOLOGICAL SCIENCES

FRIDAY 8:15 am Donald R. Shephard Seminar Building, Gold 1
SESSION A
R. WAIN, University of South Florida, presiding

8:15 am BIO-52 Effect of Temperature on Growth and Nutrient Removal Characteristics of _Azolla caroliniana_ and _Salvinia rotundifolia_. W. F. DEBUSK AND K. R. REDDY, Univ. of Florida, Sanford 32771. Separate cultures of _Azolla caroliniana_ and _Salvinia rotundifolia_ were cultured in 60 ℓ plastic tubs (0.25 m^2 water surface area) containing nutrient medium composed of 10 mg NH_4-N ℓ^{-1}, 10 mg NO_3-N ℓ^{-1} and 3.1 mg PO_4-P ℓ^{-1}, as well as Mg, Ca, K, Fe and trace elements. Azolla was grown in N-free medium. Net productivity of both azolla and salvinia was in the order 20>25>30>15>10°C. Maximum productivity was 5 g (dry wt.) m^{-2} day^{-1} and 13 g (dry wt.) m^{-2} day^{-1} for azolla and salvinia, respectively. Maximum inorganic N removal rates for salvinia were observed at 20°C. Removal of P from the nutrient medium was greatest at 25°C for both azolla and salvinia, and least at 10°C. Tissue P content of azolla and salvinia was highest at 30°C, with levels of 0.89% P and 0.77% P (dry wt.), respectively. N content of salvinia ranged from 2.71% N at 15°C to 3.16% N at 20°C. Nutrient removal was not entirely accounted for by plant uptake, but was also due to various chemical and microbiological processes.

8:30 am BIO-53 Growth and Nutrient Uptake of Pennywort (_Hydrocotyle umbellata_ L.), as Influenced by the Nitrogen Concentration of the Growth Media. J. C. TUCKER AND K. R. REDDY, Univ. of Florida, Sanford 32771. Productivity and nutrient uptake of

Hydrocotyle umbellata L. were measured in 1000 ℓ outdoor tanks during winter and spring, 1982. Nutrient levels in the growth media varied from <1 mg N ℓ^{-1} to 40 mg N ℓ^{-1}. Net productivity was highest in the treatment receiving 20 mg N ℓ^{-1} and decreased in the order of treatments receiving 40 mg N ℓ^{-1}, 10 mg N ℓ^{-1}, and 4 mg N ℓ^{-1}, respectively. Productivity was substantially lower when plants derived nutrients from sediments. Growth rates ranging from 6-26 g dry wt m^{-2} day^{-1} during winter and 4-27 g dry wt m^{-2} day^{-1} during spring were measured. Shoot lengths were found to be directly proportional to N concentration while root lengths were inversely related to N concentration. Increases in N concentration of the nutrient media resulted in similar increases in N and P concentration of the plant tissue. Nitrogen removal from the water averaged about 50% during the winter months and 79% during spring. Phosphorus removal rates for winter and spring were in the range of 64-70%.

8:45 am BIO-54 In Vivo Protein Synthesis in Developing Cotyledons of *Pisum sativum*. DONNA M. PRIBISH AND GARY N. WELLS, Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901. Pea cotyledons 17-26 days old were labeled with ^{14}C-leucine and the total protein was isolated. The proteins were separated by two dimensional polyacrylamide gel electrophoresis. The radioactively labeled or newly synthesized proteins were then analysed by fluorography to establish the pattern of protein synthesis during development. This was the first step in defining the extent of regulatory and control mechanisms of protein synthesis during development. In *Pisum sativum* there are two major groups of proteins synthesized, the albumins, synthesized during the first half of development and the globulins, synthesized in the latter half. They show little overlap in their time of production allowing one protein to be easily distinguished from another and indicating that differential protein production is a sophisticated process of control.

9:00 am BIO-55 Profiles of Merritt Island and Cape Canaveral Vegetation. C.R. HINKLE, P.A. SCHMALZER AND M.J. PROVANCHA, BIO-2, Bionetics, Kennedy Space Center 32899. East to west trending transects were established across Cape Canaveral and Merritt Island to delineate plant community distribution on the landscape. Topographic profiles were developed from USGS topographic maps upon which plant community boundaries were overlayed to scale from vegetation maps and from ground truth. Various soil-site parameters from past baseline studies, published soils maps and current ecological studies were related to the plant community distribution. Such profiles provide considerable insight toward understanding vegetation patterns along environmental gradients and provide the basis for more in-depth ecological studies at this East Central Florida, Experimental Ecological Reserve.

9:15 am BIO-56 Protection and Management of Seagrass Meadows - Is It Working? ROY R. LEWIS, III, Mangrove Systems, Inc., P.O. Box 24748, Tampa, FL 33623. Protection and management of coastal plant communities has received great attention in recent years. Major emphasis has been placed on the highly visible emergent plant communities (tidal marshes and mangrove forests) with less emphasis on the submerged macroalgal and seagrass communities. Although protected from physical destruction by the same laws that protect emergent plant communities, submergent plant communities, in particular seagrasses, are subject to very subtle stresses that can eliminate them from large areas of urbanized estuaries. These losses occur over periods of years and are often not even noticed or documented until losses are very large. An example of this problem is the loss of 81% of the seagrass cover in Tampa Bay, Florida, over the last 100 years, with continued losses expected. During the same period, emergent plant communities declined 44%, with no further losses expected due to regulatory protection. The reasons for these losses and the lessons to be learned from the uncontrolled declines in seagrass meadows are discussed.

9:30 am BREAK

9:45 am BIO-57 Red Mangrove (*Rhizophora mangle*) Restoration at Key Largo: Results After Seventeen Months. F.BOOKER, B.FLYNN, A.THORHAUG AND P. SCHROEDER, Applied Marine Ecological Services, Inc., 600 Grapetree Dr., Miami 33149. In July 1981, 11,894+ red mangrove propagules and 1,836+ seedlings were planted in partial fulfillment of the DER permit for required emergent vegetation mitigation associated with the FKAA water pipeline construction through the Florida Keys. The area had previously been impacted by the Overseas railroad and highway construction. In January 1983, an area of ca. 27,712 m^2 from 2850 m to 5992 m south of C-111 was surveyed by measuring the plants in a 60 m long sample within every 180 m long section of the impacted corridor (corridor width varied from 2 - 10 m). Survival of the restored mangroves ranged from 52 - 64% (n=2573). Mean height of the plants was 43.3 ± 9.8 cm ($\bar{x}+\sigma$), mean number of primary branches was 2.4 ± 5.5 and the mean number of leaf pairs was 10.4 ± 14.2 (n=317).

10:00 am BIO-58 Primary Production in Three Subtropical Seagrass Communities: A Comparison of Four Autotrophic Components. P.R. Jensen and R.A. Gibson. Harbor Branch Foundation, Inc., R.R. 1, Box 196, Ft. Pierce, FL 33450. A one year study was conducted on subtropical seagrass communities in Tampa Bay, the Indian River and the Little Bahama Bank. Primary production rates were compared for four autotrophic components: seagrasses (*Thalassia testudinum*, *Syringodium filiforme* and *Halodule wrightii*), associated epiphytic flora, microbenthic algae and phytoplankton. Measurements were made on a gravimetric and areal basis to determine the production base and relative importance of each component. Average seagrass production ranged from 2.44 to 11.29 mg $C \cdot m^{-2} \cdot h^{-1}$ and 0.17 to 0.38 mg $C \cdot g$ dry $wt^{-1} \cdot h^{-2}$. The data was extrapolated to cover 321 million m^{-2}, an area equivalent to the Hillsborough Bay portion of Tampa Bay. On this basis, phytoplankton were the major annual producers in Tampa Bay and the Indian River (87% and 93% respectively), whereas the yearly areal production base in the Bahamas was contributed by the seagrasses and their epiphytes (71%).

10:15 am BIO-59 Productivity Response of *Microcoleus lyngbyaceus* to Differing Light and Temperature Conditions. STEPHEN M. BLAIR AND MARTHA C. MEYER, Harbor Branch Foundation, RR 1, Box 196, Ft. Pierce, FL 33450, and Univ. of Miami, Coral Gables, FL 33146. Blooms of the blue-green alga *Microcoleus lyngbyaceus* (Kuet.) Crouan occur seasonally in the Indian River. Factors regulating these "nuisance blooms" are presently under investigation. Productivity (^{14}C uptake) was measured in a cross-gradient (light and temp.) chamber to estimate possible optimal conditions for the alga's growth. Forty-nine conditions of light and temp were measured. Photon flux densities (PFD's) ranged from 36 - 390 $uE \cdot m^{-2} \cdot sec^{-1}$ and temp. from 16 - 40°C. Productivity remained low at all temps. when PFD's were below 100 $uE \cdot m^{-2} \cdot sec^{-1}$, and at high temps (≥36). High productivity levels were found with PFD levels above 200 $uE \cdot m^{-2} \cdot sec^{-1}$ at temps. between 20 - 32°C. At low temps. (16 - 24°C) optimal PFD's (I_{opt}) were minimal. Maximum I_{opt}'s were seen at temps. between 28 and 32°C. The higher I_{opt}'s were equivalent to full sunlight intensities. These data are compared with field conditions to describe the periodicity of the blooms.

10:30 am BIO-60 The Phytoplankton of the St. Johns River Estuary. CAROLE L. DEMORT, RAY D. BOWMAN, and ART MORLOCK, Department of Natural Sciences, University of North Florida, Jacksonville, FL 32216. Twenty three sites were established within the St. Johns River System from Mayport to Lake George. Monthly plankton collections were made for a two year period. A total of 343 species of phytoplankton have been identified. Diatom species outnumbered Chlorophyte species by more than 2 to 1 in the estuary system. The number of species of Chlorophyta increased with distance from the mouth. Chlorophyte species were dominated by small-celled and colonial members of the Order Chlorococcales. Species of Cyanophyta showed no linear distribution. Phytoplankton cell counts and Chlorophyll *a* concentrations generally increased with distance from the mouth.

Exceptions to this trend occurred in highly stressed subsystems such as Cedar River and Ortega River. This study was funded by Florida SUS Sea Grant number R-EM/6.

10:45 am BIO-61 The Effect of Monomethylhydrazine on Cultures of Marine Diatoms. BRIAN W. WENDLER AND DEAN R. NORRIS, Florida Institute of Technology, Department of Oceanography, Melbourne, 32901. Monomethylhydrazine, a high energy propellant used in the U.S. space program, could possibly alter community structure of phytoplankton populations. The diatoms Skeletonema costatum (Clone Skel, Bigelow Lab), Thalassiosira pseudonana (Clone 13-1), oceanic isolate), and T. pseudonana (Clone 3H, estuarine isolate) were grown in unialgal and mixed cultures. Concentrations of monomethylhydrazine ranging from 1 ppm to 100 ppm were added to f/2 medium and cell counts made at 24 hour intervals for a period through the end of the exponential growth phase. As suggested for other toxic substances, differences in sensitivity to monomethylhydrazine may alter marine phytoplankton communities which in turn may influence higher trophic levels. Dominant species grown in the presence of other competing species have shown a reduction in dominance when exposed to toxicants. Oceanic and estuarine clones of T. pseudonana show different sensitivities to toxic substances, due to their different physiologies (Carpenter and Guillard, 1971).

11:00 am BREAK

11:15 am BIO-62 Nitrate Uptake by Two Species of Diatoms from the Indian River. JOHN M. LUDLAM AND DEAN R. NORRIS, Florida Institute of Technology, Department of Oceanography and Ocean Engineering, Melbourne, 32901. Unialgal cultures of Skeletonema costatum and Nitzschia closterium have been obtained from isolates taken from Indian River samples. Nitrate uptake rates were determined via the use of batch cultures in which nitrate was made the limiting nutrient. Eight different concentrations of nitrate were added to a series of culture flasks. Uptake rates were found by determining the difference in nitrate concentration in the medium at the beginning and end of an experimental period. Time course measurements were performed at two of the concentrations to insure that true initial uptake rates were obtained. Michaelis-Menten Kinetics are used to describe nitrate uptake by both species. The half-saturation constant, K_s, corresponds to a nitrate concentration at which one half the maximum uptake rate occurs. It reflects the relative ability of a species of phytoplankton to utilize low levels of nutrients. Comparison of nitrate uptake by both species may be useful in explaining their distribution.

11:30 am BIO-63 Isozymes as Genetic Markers in the Study of Aquatic Plants. RICHARD P. WAIN and WILLIAM T. HALLER, Center for Aquatic Weeds, Univ. of Florida, Gainesville, FL 32601. Gel electrophoresis was employed to estimate levels of allelic differentiation within and among several taxa of weedy aquatic plants. Divergence was measured using Nei's normalized genetic identity statistic (I). Little allelic differentiation (I=0.95) was found among populations of Hydrilla verticullata sampled from the eastern U.S. with the exception of one population from Washington, D.C. which possesses male flowers and exhibited many unique alleles. Very little allelic differentiation (I=0.99) was found among the fanworts Cabomba caroliniana var. caroliniana, C. c. var. multipartita, and Cabomba pulcherrima. A substantial amount of divergence (I=0.886) was discovered among broad and narrow-stemmed forms of the alligatorweed Philoxeroides alternanthera. These results are discussed in relation to taxon identification and evolutionary potential.

11:45 am BIO-64 Physiological Responses of Hydrilla to Treatment by the Inert Dye Aquashade. DENISE C. MANKER AND DEAN F. MARTIN, Chemical and Environmental Management Services (CHEMS) Center, Department of Chemistry, University of South Florida, Tampa, Florida. The pernicious, freshwater weed Hydrilla verticillata

Royale was immersed in solutions of well water containing three parts per million of Aquashade. Growth rate was measured by comparing initial wet weight with the wet weight after one week for control and test samples. Photosynthetic and respiratory rates were measured using a Warburg apparatus. These methods were employed to investigate Aquashade's mechanism of action on growth inhibition in Hydrilla. Possible mechanisms, including shading and photodynamic action, will be reviewed.

12:00 n BIO-65 Isolation of Rare Imino Acids From Calliandra. Lee A. Swain and John T. Romeo, Dept. of Biology, Univ. of South Florida, Tampa, FL 33620. CIS-4-Hydroxypipecolic acid and 2,4-CIS-4,5-TRANS-4,5-dihydroxypipecolic acid were isolated from leaves of Calliandra pittieri. This is the fourth monohydroxy and the fourth dihydroxy isomer of pipecolic acid to be isolated from the genus Calliandra (Mimosoideae). Freshly collected leaves of Calliandra pittieri were extracted with aqueous ethanol and separated by ion exchange column chromatography. Both compounds were isolated using a Dowex 50 cation exchange resin and eluting with 1.5 N HCl. This was followed by ascending paper chromatography and high voltage paper electrophoresis to obtain pure crystals for characterization by IR and NMR spectroscopy. R_f values in five chromatographic systems match those of known standards. These compounds bring to ten the number of rare nonprotein imino acids detected in Calliandra. A method for resolution of all ten compounds is described.

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 2:45 pm Donald R. Shephard Seminar Building, Gold 1
SESSION B
C.A. LUER, Mote Marine Laboratory, presiding

2:45 pm BIO-66 Assessing the surface water impacts of groundwater withdrawals by means of multiple regression analysis. P. M. DOORIS, H. M. BRYANT, AND M. LOPEZ. Southwest Florida Water Management District, 5060 U.S. Hwy. 41 S, Brooksville, 33512. The relationships among several hydrologic parameters, including groundwater pumpage, were examined in an effort to identify the importance of each in determing stages on a given lake. Approximately 25 lakes, all located in Hillsborough County, were studied. Variables for monthly pumpage, lake stage, rainfall, lagged (30-day) rainfall and lagged (30-day) lake stage were created and analyzed using step-wise elimination regression techniques. Equations were developed which described the interrelationship among the variables and permitted a short-term prediction of lake stage under a given set of conditions. These models have been used in well field impact assessment and are being refined further. In addition, the models have been applied to stream impact assessments. The paper will discuss model development, application, and limitations.

3:00 pm BIO-67 Histological Effects of Space Shuttle Launch Toxicants on Fishes. WILLIAM E. HAWKINS, ROBIN M. OVERSTREET AND MARK J. PROVANCHA. Gulf Coast Research Laboratory, Ocean Springs, Mississippi 39564, and The Bionetics Corporation, Kennedy Space Center, Florida 32899. During launches of the space shuttle from Kennedy Space Center, fish kills in nearby lagoons have occurred. Preliminary histopathological studies were conducted on control and exposed specimens of the mosquitofish, Gambusia affinis, and sailfin molly, Poecilia latipinna. Gills of control fish failed to exhibit gill damage, however, exposed specimens showed a spectrum of changes. These anomolies varied both among different specimens and among gills of individual specimens. Mild changes included lifting of the outer epithelial layer of the gill to more severe cases involving the erosion of gill lamellae with hemostasis in both afferent and efferent gill vessels. Pericardial edema was observed in the severe cases. In summary, fish subjected to drastic environmental alteration involving pH changes and possibly metal intoxication exhibited histopathological alterations sufficient to kill them.

3:15 pm BIO-68 Comparison of Hybrid Grass Carp and Grass Carp. JANINE L. CALLAHAN AND JOHN A. OSBORNE, Department of Biological Sciences, University of Central Florida, P.O. Box 25000, Orlando 32816. Numerous methods have been used in an attempt to control the exotic *Hydrilla verticillata* with varying degrees of success. The grass carp (*Ctenopharyngodon idella*) has shown its ability to control or reduce the growth of hydrilla in various studies, however, the potential exists for the grass carp to escape into rivers, overpopulate, and denude the native vegetation. The hybrid grass carp, which is considered sterile, is being studied as a weed control agent, but morphological deformities and low feeding rates were prevalent in early spawns. These problems were assumed to be corrected in the 1981 spawn, which resulted in a functional triploid hybrid grass carp, though our comparison showed little difference in the hybrid grass carp produced in 1979, 1980, and 1981. In feeding studies, the 1981 hybrid grass carp was more efficient, consumed less vegetation than fish from the 1979 and 1980 spawns, and therefore is considered less useful as a weed control agent.

3:30 pm BIO-69 Aspects of the Biology of *Aeromonas hydrophila* with Respect to the Striped Mullet, *Mugil cephalus* L., in the St. Johns River. GERALD E. FENSCH, J.A. OSBORNE and J.F. CHARBA, Department of Biological Sciences, University of Central Florida, Post Office Box 25000, Orlando, FL 32816. The aspects of the biology of *Aeromonas hydrophila* with respect to a striped mullet (*Mugil cephalus* L.) nursery ground were examined. *A. hydrophila* density in the natural water was found to be strongly correlated with water turbidity and weakly correlated with water temperature. No correlations were found with depth, dissolved oxygen, pH, total alkalinity, specific conductivity or chlorophyll$_a$ pigment concentration in the water. *A. hydrophila* densities/g dry weight of stomach contents were found to be correlated with chlorophyll$_a$ pigment concentration/g dry weight of stomach contents. The survivability of striped mullet after capture by electroshocking was increased from 0% to almost 100% through the use of a fish tranquilizer (Quinaldine) and a reduction of crowding which reduced stress.

3:45 pm BREAK

4:00 pm BIO-70 Nurse Sharks of Big Pine Key: Population Dynamics and Growth Rates. JEFFREY C. CARRIER, Department of Biology, Albion College, Albion, MI 49224. Of 61 nurse sharks (*Ginglymostoma cirratum*) tagged and released from Big Pine Key (Florida Keys), 12 different animals have been recaptured (19.7%). Animals taken in the study averaged 124.4 cm in length and 10.1 kg in weight, with approximately equal numbers of males and females. The average interval between initial capture and recapture was 260 days with average changes in length of 14.1 cm/year and average changes in weight of 5.0 kg/yr. Length/weight histograms prepared from the data provide an equation for in-field approximation of weight from length measurements of $y = 0.189x - 13.3$ (y = weight; x = length; correlation coefficient 'r' = 0.930). The use and comparative success of 3 types of external tags is summarized and evaluated, and preliminary results of ultrasonic telemetric tracking are presented.

4:15 pm BIO-71 Breeding, Embryonic Development, and Early Growth of the Clear-nosed Skate (*Raja eglanteria*) in Captivity. CARL A. LUER, Mote Marine Laboratory, 1600 City Island Park, Sarasota 33577. In our laboratory, adult clear-nosed skates have been bred successfully, eggs have been harvested, embryonic stages have been described, and the initial year's growth has been closely monitored on the newborn animals. Eggs are laid in pairs, the time interval between the appearance of successive egg pairs varying from 2-10 days. Laying continues for several weeks to the extent that a single female is capable of producing 20-30 pairs of eggs. Development within the egg case lasts about 13 weeks. Monthly measurements of total length, disc width, and body weight have been obtained on approximately 50 hatchlings. By 9 months of age, the young skates average around 50% of the size dimensions and about 15% of the body weight of sexually mature specimens. Due to their relative ease of handling and maintenance, and their ability to breed and produce offspring in captivity, the clearnosed skate may prove to be a useful laboratory animal model for numerous research applications.

4:30 pm BIO-72 Fecal Study of the Food Habits of the Manatee (Trichechus manatus) at Homosassa Springs, Florida. KIRK B. SMITH, DALE E. MILLER AND JOHN G. MORRIS. Dept. of Biol. Sciences, Fla. Inst. of Technology, Melbourne, FL 32901. Manatee feces were collected in February, 1982 from animals congregated at Homosassa Springs, Florida. Prepared reference slides of plant epidermis were used in identification of plant fragments found in the feces. Percent frequency of occurrence of food items in the study area and in the fecal samples were compared. Of the six plant species examined thus far, four showed a higher percent frequency of occurrence in the fecal samples than in the environment. The results suggest a possible preferential selection for these food items by the manatee. The digestibility and degree of plant tissue fracturing in the digestive tract were not dealt with in this study and may influence the results.

4:45 pm BIO-73 The Florida Natural Areas Inventory - A Description and Status Report. STEVE GATEWOOD, Florida Natural Areas Inventory, 254 East 6th Avenue, Tallahassee 32303. The Nature Conservancy, under contract to the Florida Department of Natural Resources, has established a heritage program, the "Florida Natural Areas Inventory", to identify significant features of the state's natural environment. Information on the status and distribution of exemplary biotic communities, rare and endangered plants and animals, geological and other natural features is collected, stored and analyzed in an integrated data management system. Map, manual, and computer files keep information organized and accessible. The inventory is a cumulative process in which data are continually updated and refined as additional information becomes available and the status of "elements" change. Access to data presently distributed throughout the state is essential if the program is to become an effective repository available to a variety of users. A description of the program will be provided as well as a summary of information processed to date.

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 8:15 am Donald R. Shephard Seminar Building, Gold 1
SESSION C
J.M. LAWRENCE, University of South Florida, presiding

8:15 am BIO-74 Absorption of nutrients of the coral Pocillopora damicornis (L.) by the echinoid Eucidaris thouarsii (Val.). JOHN M. LAWRENCE, Dept. of Biol., Univ. So. Fla., Tampa, 33620. The absorption efficiency for E. thouarsii fed P. damicornis is 44.7% for carbohydrate, 85.3% for protein, and 69.3% for lipid. E. thouarsii fed P. damicornis absorbs 0.402 mg carbohydrate, 2.814 mg protein, and 1.108 mg lipid for each g of *P. damicornis* ingested. *E. thouarsii* fed *P. damicornis* absorbs 0.201 mg carbohydrate, 1.407 mg protein, and 0.554 mg lipid per individual per day. *E. thouarsii* fed *P. damicornis* absorbs 0.824 x 10^{-3} kilocalories carbohydrate, 7.950 x 10^{-3} kilocalories protein, and 5.235 x 10^{-3} kilocalories lipid per individual per day. Despite the high efficiency of digestive absorption of organic constituents of the coral ingested, *E. thouarsii* must consume large quantities to meet its nutritional requirements.

8:30 am BIO-75 Oxygen Uptake by Monovalve Preparations of the Freshwater Clam *Elliptio buckleyi* (Lea). MICHAEL A. VITALE AND FRANK E. FRIEDL, Department of Biology, University of South Florida, Tampa, FL 33620. The clam *Elliptio buckleyi* can be obtained locally and maintained in the laboratory for several months. To facilitate use in investigations, one valve is removed to expose the animal. These "monovalve" preparations survive several days in well water and initially show an oxygen uptake of about 0.013 mg O_2/g wet body wt/h at 24.5°C. This respiratory use appears to be within a range found for intact clams and is constant, not being subject to interruption of ventilation. Uptake curves are generally linear to low partial pressures (about 15 Torr). As first prepared, "monovalve" clams appear functionally similar to intact animals and should prove useful in physiological and metabolic studies.

8:45 am BIO-76 Tree Preference in the Arboreal Snail *Orthalicus reses* (Say) (Gastropoda: Bulimulidae). JANE E. DEISLER, Florida State Museum and Dept. of Zoology, University of Florida, Gainesville 32611. The host trees of *Orthalicus reses* in the Florida Keys were determined. A qualitative examination of the distribution of the snail on trees at three sites indicated that the snail showed no tendency to occur more frequently than would be expected by random distribution on any of the tree species at those sites. The occurence of the snail on smooth-barked and rough-barked trees was analyzed statistically. The results of the analysis showed that the snail demonstrated no significant preference for one bark type over the other. The conclusion drawn from this study is that *O. reses* is not limited by the species of tree available for colonization. This study was supported by DSR Seed Grant A-I-26 issued to Fred Thompson, Florida State Museum, by the Division of Sponsored Research, University of Florida.

9:00 am BIO-77 The Effect of Salinity on Oxygen Consumption and Ammonium Excretion in Starved *Luidia clathrata* (Say) (Echinodermata: Asteroidea). CHANG-PO CHEN AND LYNDA A. SMITH, Department of Biology, University of South Florida, Tampa, 33620. *Luidia clathrata* were collected from Tampa Bay in mid-September (28°C, 16o/ooS) and then maintained in the laboratory without food. One group of individuals was maintained at 16o/oo; another group was gradually transferred to 26o/oo and then either maintained at 26o/oo or gradually transferred back to 16o/oo. The rate of oxygen consumption was significantly greater in individuals maintained for at least 5 days at 26o/oo than those maintained at 16o/ooS ($\bar{x} \pm$ SD = 2.22 ± 0.49 and 1.56 ± 0.29 ug at O_2/h/g wet wt, respectively). The mean rate of ammonium excretion for all groups varied from 0.06 - 0.12 ug at N/h/g wet wt.

9:15 am BIO-78 Comparison of Two Sampling Techniques for Fouling Community Studies. SUSAN J. SMITH, B. SCHUSTER and WILLIAM E. BROS, Biology Dept., Univ. of South Florida, Tampa, FL 33620. Point sampling is a common method employed to estimate percent cover and species richness of fouling communities. We compared results of this technique to a quadrat sampling method. The quadrat method was developed to accurately determine species richness because the point sampling method tends to underestimate this parameter (particularly for motile species). Species richness was determined for total organisms and for three subgroups based on motility; motile, sessile and semi-sessile. Both methods were compared to a planimetric control for estimates of percent cover for sessile species.

9:30 am BIO-79 Glycolytic Enzymes in the Pyloric Caeca of Luidia clathrata (Say) (Echinodermata: Asteroidea). LYNDA A. SMITH, Department of Biology, University of South Florida, Tampa, 33620. Activities of the glycolytic enzymes were measured at pH 7.5 and 25 - 26°C. The apparent specific activities (mean ± S.D., n=5) of hexokinase, phosphofructokinase, triosephosphate isomerase, glyceraldehyde-3-phosphate dehydrogenase, pyruvate kinase and lactate dehydrogenase were 0.014 ± 0.004, <0.001, 0.528 ± 0.132, 0.009 ± 0.002, 0.016 ± 0.005, and 0.003 ± 0.001 umoles/ min/mg protein, respectively. The overall glycolytic activity is relatively low when compared to other invertebrate studies.

9:45 am BREAK

10:00 am BIO-80 Seasonal Changes in Activity of Luidia clathrata (Echinodermata: Asteroidea). STEPHEN A. WATTS, Dept. of Biology, Univ. of South Florida, Tampa 33620. Luidia clathrata in Tampa Bay exhibited seasonal changes in activity as determined by changes in the righting response (righting time) and prey-handling time. Activity was lowest in the winter and highest in the summer. Activity increases with increasing temperature and decreases with decreasing salinity. Laboratory activity studies indicate that Luidia clathrata does not acclimate to temperature. Decreased salinity, due to late-summer rains, apparently decreased the activity of the asteroids. Low activity in the late summer and winter may result in decreased feeding and nutrient storage, thereby decreasing the reproductive potential of the asteroids the following spring.

10:15 am BIO-81 Isoenzyme and Protein Analysis of the Rotifer (Brachionus plicatilis) by Polyacrylamide Gel Electrophoresis. BRUCE C. WINKLER, TERRY W. SNELL & EDWARD HILL, Division of Science and Math, University of Tampa, Tampa, FL, 33606. The isoenzyme composition of fifteen strains of the rotifer (Brachionus plicatilis) will be reported. The following six enzymes were studies: aspartate transaminase, malate dehydrogenase, acid phosphatase, alkaline phosphatase, esterase and 6-phosphogluconate dehydrogenase. In addition, the results of an extremely sensitive new silver stain for protein will be reported. The genotypes at twelve loci will be characterized for each of the rotifer strains and the similarities among temporally, spatially and geographically separated populations will be discussed.

10:30 am BIO-82 Spiraperturate Pollen of Thunbergia alata Bojer ex Sims. METWALY SHETA and SHEILA D. BRACK-HANES, Eckerd College, St. Petersburg, FL 33733. Thunbergia alata Bojer ex Sims, a member of the Acanthaceae family which occurs in Florida, has an unusual form of pollen. The germinal furrow pattern is that of a spiral on the spherical grain. In this study, electron microscopy was used to observe pollen wall development beginning with bacula and furrow formation.

10:45 am BIO-83 The Endodermis of a Fossil Lycopod. JUDY S. LAWRENCE and SHEILA D. BRACK-HANES, Eckerd College, St. Petersburg, FL 33733. Paurodendron, a structurally preserved lycopod rhizomorph from the Middle Pennsylvanian, has been found with an endodermis characterized by well-developed Casparian strips. Such a mature endodermis develops, in living lycopods, as a response to fluctuating periods of moisture and dryness. This is further evidence that the Carboniferous was a time of extensive temperature to subtropical environments.

11:00 am BIO-84 A Scanning Electron Microscope Study of Gracilaria Reproductive Structures. JOHN R. FLEMING, SHEILA D. BRACK-HANES, and SUSAN B. GALLAGHER, Eckerd College, St. Petersburg, FL 33733. Gracilaria tikvahiae McLachlan, a red alga in the Gracilariaceae family, occurs abundantly in the Tampa Bay area of Florida's west coast. Spores and cystocarps were examined with the scanning electron microscope to determine their morphological characteristics.

11:15 am BIO-85 Morphological Changes in the Adenohypophyseal Basophils in the Protogynous Black Sea Bass, *Centropristis striata* During an Artificial Spawning Regime. Cynthia A. Zahnow, Eckerd College, St. Petersburg, Fl 33733. Morphological changes in the basophils of *Centropristis striata* were observed and correlated with ovotesticular maturation. Male and female *C. striata* were held in an artificial photoperiod and temperature regime until one week post spawning. After approximately 50 days, a small percentage of female *C. striata* had completed vitellogenesis and several males had completed spermatogenesis. Typical secondary sex characteristics were evident in males. At predetermined bi-weekly intervals, pituitary glands and female and male phases of ovotestes were excised from female and male fish respectively, and evaluated histologically. Data revealed a correlation between basophilic morphological changes in the adenohypophysis and ovotesticular maturation.

SATURDAY 11:30 am Donald R. Shephard Seminar Building, Gold 1
BUSINESS MEETING: Biological Sciences Section
D. TESTRAKE, University of South Florida, presiding

SATURDAY 1:15 pm Donald R. Shephard Seminar Building, Gold 1
SESSION D
H. MUSHINSKY, University of South Florida, presiding

1:15 pm BIO-86 Activity of Citrate Synthase (EC 4.1.3.7) in *Luidia clathrata* (Say)(Echinodermata:Asteroidea) after hypo- and hyperosmotic exposure. ADAM G. MARSH and KEITH WALTERS. Dept. of Biology, Univ. of South Florida, Tampa, 33620. Animals were slowly transferred to 26 and 16 o/oo(s) and held for seven days. The assay for activity used artificial seawater at the appropriate salinity. Citrate synthase activity varied inversely with salinity. Activity significantly increased (P 0.05) in animals transferred to 16 o/oo but did not significantly decrease in animals transferred to 26 o/oo. Citrate synthase may be ionically regulated during osmotic exposure.

1:30 pm BIO-87 Ionic inhibition of Citrate Synthase (EC 4.1.3.7) from the Phyloric Caeca of *Luidia clathrata* (Say)(Echinodermata:Asteroidea). ADAM G. MARSH. Dept. of Biology, Univ. of South Florida, Tampa, 33620. Partially purified citrate synthase has Km values of 3.1 and 33.2 um for oxaloacetate and acetyl-coA, respectively. Na has a greater inhibitory effect than K on activity; Mg has a greater effect than Ca. Divalent ions have a greater inhibitory effect than monovalent ions. Ionic regulation of citrate synthase may increase production of citrate at low salinities, providing a pathway for carbon skeletons from protein degradation to enter carbohydrate/lipid metabolism.

1:45 pm BIO-88 The effect of nutritional condition on ingestive conditioning in *Luidia clathrata* (Say) (Echinodermata: Asteroidea). JAMES B. McCLINTOCK, Department of Biology, University of South Florida, Tampa, FL 33620. Initially, individuals showed no preference (as evidenced by contact chemoreception and teloreception) between clam (*Donax variabilis*) and shrimp (*Penaeus duorarum*) foods. Individuals fed 0.5 g wet wt shrimp/day over a 21-day period showed significant preferences from shrimp over clam food. Individuals fed 0.5 g wet wt clam/day over a 21 day period showed no teloreceptive preferences, but significant contact chemoreceptive preference for clam over shrimp food. Individuals not fed for 21 days showed no preference for either food. Similar ingestive conditioning is exhibited among individuals which were starved for a 3-month period prior to conditioning. However, nutritional condition may influence selectivity as starved individuals showed a preference for shrimp food following the starvation period. Teloreceptive-response times were significantly lower and ingestion rates (contact chemoreception) significantly higher among starved individuals.

2:00 pm BIO-89 The Effects of Hunger and Satiation Upon Feeding Behavior of Lytechinus variegatus Lamarck (Echinodermata: Echinoidea). T. S. KLINGER, Dept. of Biology, Univ. of South Florida, Tampa 33620. The frequency of feeding has no significant ($p \leq 0.05$) effect upon the feeding rate of large Lytechinus variegatus. Equivalent amounts of artificial food (2x2x1 cm 4% agar blocks containing 5% dry weight Thalassia testudinum, tissue to volume) are consumed per feeding bout whether the sea urchins are fed at daily, 3-day, or 6-day intervals. Small L. variegatus consume significantly ($p \leq 0.05$) less when fed at 3- or 6-day intervals than when fed daily, an effect of starvation. The frequency of individuals expressing spontanious feeding behavior (movement of the peristome and teeth in the absence of food stimuli) is only slightly lower after periods of starvation than after periods of feeding ad libitum. These data suggest that L. variegatus feeds at a constant rate, independent of hunger or satiation within the constraints of the well-being of the animal.

2:15 pm BREAK

2:30 pm BIO-90 Precocene II: Stability and Effects Upon Wood-Boring Isopods. STANLEY A. RICE, RICHARD H. PIERCE AND ERNEST D. ESTEVEZ, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. The effects of precocene II in seawater solution were determined for two species of wood-boring isopods, Sphaeroma terebrans and Limnoria tripunctata. A precocene II concentration of 30 ppm killed all S. terebrans after 10 day exposure. Precocene II was more toxic to L. tripunctata, producing a 96 hour LC_{50} value of 8.4 ppm. Wood boring activity of L. tripunctata ceased after 48 hours exposure to 20 ppm precocene II. Exposure to this chemical affected molting rate in S. terebrans but not in L. tripunctata. Chemical analysis of precocene II in solution employed reverse phase high performance liquid chromatography utilizing an ultraviolet detector at 254 μm. Analyses over time indicated that precocene II was stable in seawater solution. This research was supported, in part, by a grant from the Florida Sea Grant Program.

2:45 pm BIO-91 The Population Dynamics of the Stone Crab (Menippe mercenaria) in Everglades and Biscayne National Parks. T.M. BERT, J. DODRILL, G.E. DAVIS, AND J. TILMONT, Everglades National Park, Research Center, Homestead, FL 33030. Temporal and spatial variations in the distribution, relative abundance, sex ratio, size class frequency, and reproductive effort of stone crabs was assessed for one year throughout south Florida nearshore national park waters using traps. The data indicate that a mojor nursery area for stone crabs exists offshore from southwest Florida's two major terrestrial drainage systems, the Big Cypress and Everglades estuaries. Stone crabs apparently disperse from that area southward toward the Florida Keys and into Florida Bay. The stone crabs in Biscayne National Park are apparently not locally recruited and may be dispersing from farther north along the east coast of Florida.

3:00 pm BIO-92 Factors Affecting Sexual Reproduction in Rotifers. NIGEL C. CORNWALL and TERRY W. SNELL, Division of Science, University of Tampa, Tampa, FL 33606. As cyclical parthenogens, rotifers can reproduce either asexually or sexually. We investigated various factors that affect the frequency of sexual reproduction in the rotifer *Brachionus plicatilis*, including temperature, salinity, food level and food type. The highest levels of sexual reproduction were observed at moderate temperatures, salinity, algal concentrations above 2.5 ug/ml and on a mixed diet of *Chlorella* and baker's yeast. Considerable variation among strains was observed in the level and duration of sexual reproduction, with some strains reproducing sexually nearly continuously and others only infrequently. The evolutionary significance of these different levels of sexual reproduction will be discussed.

3:15 pm BIO-93 Temperature and moisture relationships of *Tenebrio obscurus* (Coleoptera). LISA ROSEN and F. PUNZO, Dept. of Biology, University of Tampa, Tampa 33606. Studies were conducted to ascertain the effects of temperature, relative humidity (RH) and period of exposure on the survival capacity of *Tenebrio obscurus* larvae, as well as other aspects of its thermal biology including the determination of upper and lower lethal temperatures. In addition, an analysis of temperature effects on cuticular water loss was also undertaken. Upper LT$_{50}$ values were 42.6 deg C at 72% RH, and 39.2 deg C at 12% RH. Lower LT values were -4.4 deg C at 12% RH, and -5.9 deg C at 72% RH. Percent survival at high stressful temperatures decreased with increasing periods of exposure. The comparative evaluation of the thermal biology of *Tenebrio obscurus* with other, better known tenebrionids will be discussed.

3:30 pm BREAK

3:45 pm BIO-94 The Occurrence of Trichomycetous Fungi in the Hindguts of Seven Species of Brachyuran Crabs from Tampa Bay. ROBERT A. MATTSON, Department of Biology, University of South Florida, Tampa, FL 33620. The hindguts of seven species of brachyurans from Tampa Bay were examined for the occurrence of fungi of the class Trichomycetes. The species of crabs examined represented the families Grapsidae (3 spp.), Ocypodidae (2 spp.), and Xanthidae (2 spp.). Fungal infestation (percent of individuals in sample infested with fungi) was 0% (the xanthids *Panopeus herbstii*, n=10, and *Eurytium limosum*, n=3), 18.2% (the ocypodid *Uca pugilator*, n=11), 35.7% (the grapsid *Sesarma cinereum*, n=14), 72.7% (the grapsid *Sesarma reticulatum*, n=22, and the ocypodid *Uca rapax*, n=11), and 100% (the grapsid *Aratus pisonii*, n=11). All fungi observed belonged to the order Eccrinales.

4:00 pm BIO-95 Histochemistry of carbohydrates and proteins in the toad saccule. R.A. WINEGAR AND J.C. PARK, Dept. Biological Sciences, Fla. Institute of Technology, Melbourne, FL 32901. The composition of the saccular otolithic organ has been technically difficult to determine. The toad offers a suitable model for study because the saccule is very large compared to other animals. We examined the staining characteristics of the otolithic membrane and the otolithic mass in the common Florida toad, *Bufo terrestris*. Periodic acid-Schiff (PAS), Alcian blue (pH 2.5 and pH 1), and Millon's tyrosine-reactive stain were used. The otolithic mass stained positively with Alcian blue at both pHs, indicating a highly acidic mucosubstance. The otolithic membrane, the saccular-delimiting membrane and the glycogen-laden hair cells were PAS-positive, indicating the presence of neutral polysaccharides. The otolithic mass and hair cells stained positively for tyrosine. This evidence suggests that the ground substance of the otolithic mass contains an acidic mucoprotein.

4:15 pm BIO-96 On the Relationship Between Fire and the Herptile Community on a Sandhill in Florida. Henry R. Mushinsky and E. Black. Biology Department, USF, Tampa, FL 33620. We are reporting on a pilot study of the relationship between periodic fire and a Florida sandhill herptile community. We used drift fences to sample three plots of land that are maintained on different burn cycles. The control area has not been burned in about 15 years, the other fields are on one and two year cycles and all our burning occurs in the spring. We trapped 27 species including 9 snakes, 6 lizards, 4 turtles and 8 frogs. The amphibians show a seasonal pattern that is consistent from plot to plot and highly correlated with rainfall. The most common snake, Tantilla relicta, is more abundant in the control plot. The lizard, Cnemidophorus sexlineatus, is seasonally abundant on all three study plots, however the one-year plot has a higher proportion of young and juvenile lizards suggesting they are moving in from elsewhere.

4:30 pm BIO-97 Food supplementation of small rodents in Sand Pine Scrub. BRENDA L. YOUNG and I. JACK STOUT, Univ. of Central Fl., Orlando 32816. We conducted a two-year study to evaluate population fluctuations of Peromyscus gossypinus, P. floridanus, and Ochrotomys nuttalli in response to supplementary food. Routine demographic data were collected for 1 year on 2 study areas. For the last year sunflower seeds were provided on one of the two (0.52 ha) grids. Seeds were supplied in feeders designed to deny access to larger animals. The availability of natural foods such as insects and acorns was monitored. P. gossypinus and O. nuttalli appeared to increase in early summer on the food augmented grid. By mid-summer natural foods, viz., insects and acorns were in abundance and captures diminished from July through November on both grids. Capture success increased during the winter as natural foods were reduced in availability. In summary, the clearest indication of food limitation appeared to be the winter increase in abundance of P. gossypinus and O. nuttalli. Partial support for the study was provided by Sigma Xi.

COMPUTER SCIENCES AND MATHEMATICS

FRIDAY 8:15 am Donald R. Shephard Seminar Building, Black 2
P. PAPACOSTA, Stetson University, presiding

8:15 am CSM-98 FORTH, An Extensible System. THOMAS HAND, Florida Institute Of Technology, Melbourne, FL 32901. FORTH is a computer software system that contains an editor, assembler, and operating system. FORTH has a vocabulary of words that can easily be extended to other vocabularies for specific applications. A FORTH environment along with various extensions is being studied.

8:30 am CSM-99 Bottom of the Line Low-Cost Computer Aided Design System. B.H. THRASHER, Mechanical Engineering Department, Florida Institute of Technology, Melbourne, FL 32901. This paper describes a micro-computer based computer-aided design (CAD) system which was developed under a very limited budget for use in the mechanical engineering curriculum at the Florida Institute of Technology. It attempts to fill a gap at the low end of available CAD systems. The computer selected for the system was the Commodore 8032 with the MTU graphics board. This allowed a graphics screen resolution of 320 x 200 pixels horizontal and vertical respectively. The total hardware cost of $15,000 included three complete work stations consisting of computer, dual disk drive, x-y plotter, printer and digitizer pad.

8:45 am CSM-100 Continous Variation in Parametric Linear Programming. YASSER A. HOSNI AND TIMOTHY ATKINS, Industrial Engineering Dept., University of Central Florida, Orlando, FL 32816. The behavior of the Optimal Solution as a result of predetermined continous variation (linear and nonlinear) in the parameters of a linear programming problem is programmed on a micro/personal computer. User can enter the parameters to the problem into an Apple System through conversational dialogue with the program. Program will determine and report the optimum value(s) of the objective function/variables along with the ranges of variation parameter for which the values will remain optimal - graphical representation is also given-the program is a valuable tool for practitioners dealing with models of this form, especially in sensitivity analysis cases.

9:00 am CSM-101 A PDP-11 Based Solar Data Collection System: Design, Use, and Implications for Engineering Research, JOEL H. BLATT AND JOHN C. LOVE, Physics and Space Sciences Department, Florida Institute of Technology, Melbourne, 32901. A 48 channel data collection system was built using a DEC PDP-11/23 minicomputer to study the operation of solar hot water systems. The system was designed to collect a day's worth of data at a rate of from 1 scan/second to 1 scan/5 minutes for 48 channels with a real time print out of the data. Simple software changes enabled the system to record data from a concrete crushing experiment consisting of 3 data channels sampled at rates of from 1000 samples/sec. to 5000 samples/sec. for short periods of time (typically 3 sec.). Computer generated plots of the data were available 5 minutes after the experiment. This research was supported in part by a grant from the State of Florida through the Florida Solar Energy Center.

9:15 am BREAK

9:30 am CSM-102 Design and Use of Decision Support Systems. FREDERICK B. BUONI GENEVIEVE E. JOSEPH AND BARTON R. BECK, Florida Institute of Technology, Melbourne, FL 32901. Decision Support Systems, DSS, are interactive, computer-based systems to assist humans in decision making tasks. A study is being conducted to determine the factors which affect acceptance and Use of DSS in practice. Initial use of a DSS appears to be accepted for fairly structured problems. Growth to applications for less structured problems appears to depend upon favorable experiences with the structured case. The study includes cases from industry and government.

9:45 am CSM-103 Interconnecting Computer Systems. DAVID CLAY, Florida Institute of Technology, P. O. Box 1150, Melbourne 32901. The future possibility of Florida institutions merging their computer resources into a state-wide utility is available. This paper presents the idea of local/regional computer networks and the problems that must be solved to produce a functionally efficient computer network for the Florida academic community.

10:00 am CSM-104 Relativity and the Microcomputer in the Linear Algebra Course. GARETH WILLIAMS, Mathematics Department, Stetson University, DeLand, FL 32720. Applications and the use of microcomputers in Linear Algebra are discussed. Special Relativity is introduced as an application of an inner product. A voyage to Alpha Centauri is simulated on a microcomputer.

10:15 am CSM-105 Using Computers to Aid the Handicapped. MICHAEL E. VALDEZ, Florida Institute of Technology, Melbourne, Florida. The large progress in computer technology and the reduction in costs, permits the use of computers in new applications. To aid a speech impaired person the computer must be portable, inexpensive and easy to use. This last condition requires the development of programs to translate English test into phonemes used by the speech synthesizer. The handicapped person then types text that is spoken by the computer. This paper analyzes these constraints and the solutions obtained at F.I.T.

10:30 am BREAK

10:45 am CSM-106 Video Computer Analysis and Image Storage of Human Chromosomes. KERRY B. CLARK AND JOHN C. HOZIER, Biological Sciences Department, Florida Institute of Technology, Melbourne 32901. Manual and photographic processing (karyotyping) of human chromosome smears is a tedious process presently requiring about five hours per smear. This processing period is a major factor in the cost of chromosome analysis. We have assembled a hardware/software system which digitizes microscope images from a video microscope. Individual chromosomes are selected from the screen with a light pen, filed on floppy diskette, and reassembled in standardized format as a finished karyotype image. The final image is storable on floppy diskette or other media to provide permanent documentation of the analysis. Processing can include simple contrast enhancement and deletion of chromosome overlaps. Production of finished karyotype images from prepared smears requires a maximum of about 30 minutes in the current version of the software.

11:00 am CSM-107 Color Graphics from Black-and-White Computers. FREDERICK B. ESSIG, Department of Biology, University of South Florida, Tampa, 33620. A simple BASIC program for generating color graphics on black-and-white monitors, via a 3-color separation process is described. The screen is scanned 3 times, once for each of the primary colors, and exposed onto a single frame of color film through red, green and blue filters. Advantages of this system include higher resolution (no phosphor dots) on the final photograph than can be obtained from color monitors, substantially lower equipment costs, and a virtually infinite range of available colors and shadings. Applications will include all areas of artwork for education and scientific presentations.

11:15 am CSM-108 Computer Assisted Instruction In Statistics. Arthur Gutman, Department of Psychology, Florida Institute of Technology, Melbourne, FL 32901. A Computer Assisted Instruction package written with high resolution character sets will be described. The package contains modules for instruction and quizzing, as well as self-standing utilities to analyze data.

FRIDAY 11:30 am Donald R. Shephard Seminar Building, Black 2
BUSINESS MEETING: Computer Sciences and Mathematics Section
P. PAPACOSTA, Stetson University, presiding

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
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FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
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ENGINEERING

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SATURDAY 8:15 am Donald R. Shephard Seminar Building, Black 1
T.V. BELANGER, Florida Institute of Technology, presiding

8:15 am ENG-109 Ambient Air Quality Monitoring and Computer Aided Mapping. N. THOMAS STEPHENS AND ADIL N. GODREJ, Florida Institute of Technology, Melbourne, FL 32901 and Virginia Tech, Blacksburg, VA 24061. Measurements of ambient and point source related concentrations of air pollutants and air quality parameters were obtained with aircraft mounted monitors and automatically logged in digital form during flight. During the summer months of 1981, sulfur dioxide levels of 5 to 15 ppb, nitrogen oxides levels of 2 to 5 ppb, and visual range as inferred from light scatter measurements from 5 to 90 miles were recorded in the Shenandoah National Park in Virginia. Results of a computerized mapping display program are presented to aid in the visualization of horizontal and vertical spatial distributions of the air pollutants.

8:30 am ENG-110 Viscosity of a Two-Component Blend of Pure Mineral Oils Versus Temperature and Composition. TADEUSZ CZYZEWSKI, D.Sci., Mechanical Engineering Dept., Florida Institute of Technology, Melbourne, FL 32901. Methodology and results of extensive investigation into combined effects of composition and temperature upon dynamic viscosity of a blend of pure non-reactive mineral oils are presented. The oils did not contain any performance improvers except for minute quantities of oxidation and corrosion inhibitors. Experiments were performed using a GDR commercial viscometer named Rheotest VEB. Viscosity range examined here was 26.5 to 1200 cP. Effect of temperature, range of 20 to 90 degrees centigrade Celsius, proved to conform to very well known empirical formulas of Vogel and Walter. Effect of composition agrees relatively well with ASTM graphs but is in disagreement or only partially agrees with simplistic formulas suggested by others. A new empirical formula is given which very well agrees with experimental data of other authors and ASTM.

8:45 am ENG-111 Drying Rate of Water Based Citrus Wax. SAFVAT KALAGHCHY, Mechanical Engineering Department, Florida Institute of Technology, Melbourne, FL 32901. To preserve citrus products for longer time, the fruits are waxed after being cleaned. To develop and use a fruit wax certain questions concerning the thermodynamic properties of the wax and the process involved must be answered in order to decide if the wax and the process are energy efficient compared to other alternatives.

This paper presents procedures for evaluation of the thermodynamic properties of a water-based citrus wax. The vapor pressure is evaluated at different concentrations. Then some actual drying experiments under different conditions of drying are performed and interrelated to the wax vapor pressure. Using a mathematical model the drying rate of the wax is predicted, and the drying time is calculated at any concentration.

9:00 am ENG-112 Estimation of the Life of Reverse Osmosis Membranes. S.C. KRANC AND R. P. CARNAHAN, College of Engineering, University of South Florida, Tampa, Florida, 33620. Reverse osmosis is a viable method for recovery of high quality potable water from salt or brackish water supplies. Frequently commercial units utilize cellulose acetate membranes operated at high pressures. In time flux decline occurs due to membrane compaction. A method of estimating production over the useful life of the membrane is presented. Power consumption and water quality are considered as a means of evaluating the operation of the membrane.

9:15 am ENG-113 Hypergolic Vapor Scrubber And Bubbler System. R.G. BARILE, J. THOMAS and F. HOWARD*. Florida Inst. Tech., Chem. Engrg. and Med. Res. Inst., Melbourne FL 32901. Hypergolic fuel and oxidizer are released from the space shuttle during fueling and defueling operations. This study was aimed at improving scrubber efficiency and avoiding certain failure modes. A small lab system was operated with gaseous N_2O_4 in N_2 or He to determine efficiency of NaOH or Na_2SO_3 solutions. A gas bubbler and a dry packed bed were also evaluated downstream from the scrubber. The same equipment was used to remove hydrazine or monomethyl hydrazine from N_2 or He. The best solutions for N_2O_4 removal were 25% NaOH followed by 20% Na_2SO_3 in the bubbler. These gave 99.99% efficiency. Fuel removal was also at 99%. Designs for full scale equipment are presented.

*NASA, JFK Space Center, FL

9:30 am ENG-114 The Influence of Magnetic Fields on Boundary Layer Heat Transfer. ALI ALP KERESTECIOGLU AND R.P. SCARINGE, Mech. Eng. Dept., F.I.T., Melbourne Florida 32901. The effects of magnetic fields on laminar free convection over horizontal surfaces has been investigated. The steady flow of electrically conducting mediums with stationary and moving boundaries has been explored via similarity solutions of the governing equations. The effects of variations in the Prandtl, Grashoff and Hartman numbers has been presented. The results indicate that significant modification of the local convective heat transfer coefficient can be achieved with high conductivity fluids or Ionized gases.

9:45 am ENG-115 Two-Dimensional Finite Element Thermal Analysis Program. FRANCIS L. STASA, Florida Institute of Technology, P.O. Box 1150, Melbourne, FL 32901. A transient and steady-state two-dimensional thermal analysis program, which may be executed on microcomputers with only 64K bytes of RAM, is described. The program includes a mesh generation scheme which is capable of generating both graded and ungraded triangular meshes. Anisotropic and heterogeneous materials are permitted, with convection, radiation (to a large enclosure), imposed heat fluxes, and nonuniform and point heat sources also routinely handled. Both constant and variable time step capability is provided. Multiple materials may be present, with the properties possibly dependent on spacial coordinates, time and/or temperature. Through the use of a user-supplied variable-property routine, the program can be used to model systems with thermostats, mass transfer, change of phase, and so forth. Because of the way in which the data is handled, the number of nodes, elements, materials, point sources, etc. are only limited by the available computer memory; for example, if fewer nodes are used, more materials are automatically accommodated.

10:00 am BREAK

10:15 am ENG-116 Factors Affecting the Optimization of the Stirling Cycle for Use as a Heat Pump. ROBERT P. SCARINGE, Assistant Professor, Mechanical Engineering Dept., Florida Institute of Technology, Melbourne, FL 32901. The effects of variations of the phase-angle, cylinder volumes, dead space, cylinder heat transfer, working fluid, and temperature on capacity and performance of a Stirling cycle heat pump have been investigated experimentally and simulated with a computer model. The results are presented as a series of curves which indicate design trends. Shortcomings in predicting the coefficient of performance via the ideal Schmidt analysis are identified, and a comparison of the simulated COP_H with experimental data, is presented for one particular non-optimum machine.

10:30 am ENG-117 **Forced Vaporization Cooling of HVDC Thyristor Valves.R. SARINGE,* F. STAUB, F. LAZERED, S. BLACK, and N. ABURL. Dept. of Mechanical Engineering, Florida Institute of Technology. Melbourne, FL, 32901. Limitations of conventional air-cooled systems have made evaporative cooling appealing. Design considerations of such a system and its operational limits benefit from the large body of two-phase flow and heat transfer information generated by nuclear and chemical industries. The data and design correlations developed in these industries, however, are applicable only within their respective ranges of operation and do not involve operation under high electrical potentials. Furthermore, because of size restrictions, HDVC power conversion equipment necessitates small, short, and interconnected passages operating under high voltage conditions, a situation which is quite different from requirements of nuclear and chemical industries. Thus, experiments had to be performed to develop the necessary understanding and design correlations for forced vaporization cooling of this equipment.**

10:45 am ENG-118 Optimum Design of Helical Springs using Nonlinear Programming. R.L. HENRY, VISITING INSTRUCTOR, AND S.M. METWALLI, ASSOCIATE PROFESSOR, University of Central Florida, Orlando, Florida 32816. This paper describes the performance of helical springs, developes the descriptive equations to form a mathematical model and describes a solution technique to provide an optimal designed spring. The objective is to minimize the weight subject to the constraints of mini-compression, maximum diameter, buckling and resonance. Once the constraints and variables are selected a method of solution is applied which allows the use of equality and inequality constraints. The SUMT penalty function algorithm is used. The penalty is decreased in an iterative solution procedure until the optimal solution is achieved. The present method improves on previous methods by allowing the consideration of more constraints and also all of the constraints are simultaneously used.

11:00 am ENG-119 Use of Computerized Digital Correlation and Laser Speckle Photography and Application in Engineering. FAISSAL A. MOSLEHY, Department of Mechanical Engineering and Aerospace Sciences, University of Central Florida, Orlando, FL 32816. The development of laser speckle photography techniques in stress analysis continue to be of great importance in experimental mechanics and future research will utilize computer applications as a method of data analysis. This paper describes and demonstrates the compatibility of speckle techniques with digital computer systems for measuring in-plane displacements and strains of objects. The research also investigates the theoretical concept and practical application of displacement measurements utilizing the correlation of a reference and deformed image.
Examples of digital correlation in data analysis are presented to illustrate the application of the technique.

11:15 am ENG-120 Transient Response Evaluation from Steady State Spectral Output of Dynamic Systems. SAYED M. METWALLI, Associate Professor, University of Central Florida, Orlando, Florida 32816. This paper is an extension of a previous paper on the same theory. The transient response is also obtained from the steady state spectral response, however, the complete steady state spectrum is not required. Only a number of points on the spectrum that equals to the number of degrees of freedom should be known. No constraints on the location or spacing of points are present in this procedure. The paper also presents the inverse procedure of finding the steady state spectral output from a transient response. The new procedure is simpler and provides the equivalence of transient and steady state responses so that the more convenient method can be used. This work has been supported in part by UCF-In-House Research Awards.

11:30 am ENG-121 Computer Aided-Design Using a Second Generation Micro Computer. B.H. THRASHER, Mechanical Engineering Department, Florida Institute of Technology, Melbourne, FL 32901. This paper presents a description of a computer-aided design (CAD) system which has been upgraded from a Commodore 8032 micro-computer based system to a MTU 130-2D micro-computer based system. The MTU 130-2D computer includes a graphics screen with 478 x 254 pixel resolution, two-1 megabyte disk drives. Several examples of mechanical drawings generated on the system are included.

SATURDAY 11:45 am Donald R. Shephard Seminar Building, Black 1
BUSINESS MEETING: Engineering Section
T.V. BELANGER, Florida Institute of Technology, presiding

ENVIRONMENTAL CHEMISTRY

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 1:15 pm Donald R. Shephard Seminar Building, Red 2
SESSION A
F.E. DIERBERG, Florida Institute of Technology, presiding

1:15 pm ENV-122 A Limnological Survey of Secondary Effluent Receiving Ponds, Brevard County, Florida. MICHAEL J. BODLE, Florida Institute of Technology, Dept. of Environ. Science and Technology, Country Club Road, Melbourne, FL 32901. Selected biological, chemical, and physical parameters were studied in a series of six irrigation ponds that receive a portion of the effluent from a municipal secondary sewage treatment plant. The ponds are on a municipal golf course and were stocked with sterile hybrids of the grass carp, _Ctenopharyngodon idella_, during the six month sampling period. Parameters analyzed include light-dark bottle estimation of primary productivity, diurnal oxygen curve estimation of community metabolism, phytoplankton, benthic macroinvertebrate, and aquatic macrophyte identification and density determination, and determination of levels of chemical nutrients, chlorophyll _a_, and suspended solids loading.

1:30 pm ENV-123 Water Quality Trends and BMP Implementation in the Headwaters of the Taylor Creek/Nubbin Slough Watershed. GARY J. RITTER AND L. H. ALLEN, JR., South Florida Water Management District, 111 SW Park Street, Okeechobee 33472. The Taylor Creek/Nubbin Slough watershed has been identified as the major source of phosphorus to Lake Okeechobee, contributing 5 percent of the total annual water budget and 30 percent of the phosphorus load. The headwaters (Otter Creek, Little Bimini, and NW Taylor Creek) provide drainage for 8 dairies, representing 29 percent of the total land area and approximately 25% of the total phosphorus load within the basin. There are three major agricultural practices throughout the headwaters (dairy, beef cattle, and citrus), the primary source of phosphorus coming from dairy operations. These phosphorus inputs can be attributed to various agricultural point and nonpoint sources of dairy wastewater runoff. An extensive water quality monitoring program as well as a program to implement best management practices (BMP's) throughout the headwaters was designed in order to evaluate the effectiveness of BMP's in alleviating the high phosphorus loads within the project area.

1:45 pm ENV-124 Agricultural Impacts On The Upper St. Johns River, Florida. Thomas V. Belanger and Scott D. VanVonderen, Department of Environmental Science, Florida Institute of Technology, Melbourne, FL 32901. Thirteen agricultural pump events were monitored during the summer of 1982 and measured discharges ranged from 13 to 282 ft^3/s. Pumped water quality varied with site, depending on land use activities in each subbasin. Discharges were generally characterized by high dissolved solids, TP, TKN, NH_4 and in some cases, BOD. Total P and total N loading from individual pumps reached high levels of 227 and 1566 kg/day, respectively. Loading rate data from various agricultural canals entering the Upper St. Johns River show varying impacts during different times of the year. Data indicate that agricultural runoff and pumpage can significantly contribute to algae blooms, heavy aquatic plant growth and fish kills occurring in the area.

2:00 pm ENV-125 Utilization of a Restored Wetland for Uptake of Nitrogen and Phosphorus in Stormwater Runoff from Upland Improved Pasture. ALAN L. GOLDSTEIN, South Florida Water Management District, P. O. Box 938, Okeechobee, FL 33472. The ability of a recreated wetland to remove nitrogen and phosphorus in nonpoint source stormwater runoff from livestock grazing operations typical in the upper Kissimmee River watershed was investigated from April 1979 through October 1982. During this time the marsh exhibited a net reduction of both parameters on an annual basis. Estimates were made of detention time versus efficiency of uptake. Preliminary results suggest that a fifty percent or greater reduction in total N and total P loads will occur with detention times in excess of 23 and 10 days, respectively.

2:15 pm ENV-126 Activity of Naturally Occurring Hydrilla Growth Inhibitors. JOHN BARLTROP AND DEAN F. MARTIN, CHEMS Center, Department of Chemistry, University of South Florida, Tampa, FL 33620. Naturally occurring hydrilla growth inhibitors have been isolated from sediment of Lake Starvation in northwest Hillsborough County and other locations [cf. P. M. Dooris and D. F. Martin, Water Resources Bull., 16, 112 (1980]. Separation of the aqueous extracts by HPLC yields two components, one of which is notably active in affecting the rate of photosynthesis and the rate of respiration of hydrilla leaves.

SATURDAY 2:30 pm Donald R. Shephard Seminar Building, Red 2
BUSINESS MEETING: Environmental Chemistry Section
F.E. DIERBERG, Florida Institute of Technology, presiding

SATURDAY 3:00 pm Donald R. Shephard Seminar Building, Red 2
SESSION B
F.E. DIERBERG, Florida Institute of Technology, presiding

3:00 pm ENV-127 Induction of Sessile-Stage Formation of the Red Tide Organism Ptychodiscus brevis by materials elaborated by Gomphosphaeria aponina. LIGIA PABON DE MAJID AND DEAN F. MARTIN, CHEMS Center, Department of Chemistry, University of South Florida, Tampa, FL 33620. Cultures of the cyanobacterium Gomphosphaeria aponina were subjected to continuous cell centrifugation, followed by chloroform extraction, and the residues from the extracts ("aponin") were tested for the ability to induce sessile formation of P. brevis. Fractionation of aponin by HPLC using a methanol-water gradient led to 30 fractions, which were tested for induction of sessile formation, as measured by an electronic particle counter. Sessile formation was identified with one fraction, and not the one that causes cytolysis. The implications will be considered. Supported by NIEHS.

3:15 pm ENV-128 Ptychodiscus brevis as a Model System for Photodynamic Action. JOHN BARLTROP, BARBARA B. MARTIN, AND DEAN F. MARTIN, CHEMS Center, Department of Chemistry, University of South Florida, Tampa, FL 33620. Six dyes were tested against the unarmoured dinoflagellate Ptychodiscus brevis, the Florida red tide organism. The number of cells surviving after 24 hours was measured relative to dye-free controls. All dyes studied appeared to induce cytolysis through photodynamic action. With one dye, neutral red, addition of a quencher (3.3×10^{-4} M sodium azide) brought about a degree of protection that was consistent with the amount expected for a quencher of singlet oxygen. Implications of the research will be considered.

3:30 pm ENV-129 Heavy Metals in Drinking Water From Cisterns on St. Maarten. ANTONIO GUMBS AND FORREST E. DIERBERG, Dept. of Environmental Science and Engineering, Florida Institute of Technology, Melbourne 32901. The significance of heavy metals (Pb, Cd, Cr, Zn) in drinking water from cisterns of single-family dwellings on St. Maarten (Netherlands Antilles) is evaluated with respect to (U.S.) drinking water standards. Metal levels in the surface waters are within public health limits. Considerable dissolution of metals occurs in the distribution system (pressure tank and supply lines), with Pb levels exceeding a public health maximum of 50 ppb approximately 8% of the time. Concentrations of metals are correlated with presence or absence of paint on catchment surface, proximity of ocean, and corrosion potential (S.I.).

3:45 pm ENV-130 Evaluation of Sorbents for Recovery of Toxic Organics from Seawater. RICHARD PIERCE, ROBERT BROWN, JAMES MULLEN, KATHY PECK AND LISA SIEGFRIED, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. Fourteen sorbents were evaluated for recovery of toxic organic substances (TOS) from seawater to select the most efficient sorbent for use in an in situ sampler. Model compounds were used to represent different classes of TOS. These compounds included: the normal alkanes, tetradecane, heptadecane and eicosane; the isoprenoid, pristane, polynuclear aromatic hydrocarbons, phenanthrene and pyrene; 'DDT representing chlorinated hydrocarbon pesticides and pentachlorophenol (PCP) representing more polar compounds. Laboratory studies showed that Tenax-GC exhibited higher recoveries of all classes of compounds than any other sorbent or mixture of sorbents tested. Field tests are presently underway.

4:00 pm ENV-131 Collection and Analysis of Volatile Organic Compounds in Air with Tenax-GC Cartridges. JOHN G. WINDSOR, JR., Florida Institute of Technology, 150 West University Blvd., Melbourne 32901. The effects on human health and environmental quality of volatile organic compounds and their photochemical decomposition products are of great concern. One way to quantitate volatile organic compounds from stationary or mobile sources, fugitive emissions, or the ambient environment is to pass a measured volume of air over a bed of solid sorbent (such as Tenax-GC) packed into a cartridge and then to analyze the cartridge by thermal desorption (GC-FID or GC/MS. This paper discusses the development and application of the sampling techniques for field studies in Houston, TX, and the Ohio River Valley. Three methods for the preparation of volatile organic standards on Tenax-GC cartridges which evolved from the studies will be discussed.

4:15 pm BREAK

4:30 pm ENV-132 The Fate of Industrial Organics in Drinking Water Aquifers. MATTHEW B. MONSEES AND J.J. McCREARY, Dept. of Environmental Engineering Sciences, Univ. of Florida, Gainesville 32611. Every year throughout Florida, thousands of pounds of waste organic compounds are dumped into percolation ponds and eventually pose a threat to groundwater supplies. The objectives of this study were to observe aerobic and anaerobic decomposition of five commonly found contaminants in groundwater. The compounds were chosen from five different chemical classes; aldicarb (carbamate), benzene (aromatic), ρ-cresol (substituted phenol), naphthalene (polynuclear aromatic) and methylethylketone (ketone). Enriched and non-enriched bacterial cultures autochthonous to local groundwater were used with and without added micronutrients. Disappearence of organic compounds was monitored using GC/MS and MS/MS methods. Results indicated a rapid aerobic removal of the ketone and naphthalene with a slower removal of benzene. The decomposition of aldicarb was very slow and appeared to be chemical in nature. Reports of anaerobic degradation and determination of metabolites will also be given.

4:45 pm ENV-133 Pentachlorophenol Contamination in a Sewage-Aquaculture System. JOSEPH J. SEIDLER, FORREST E. DIERBERG, AND RICHARD PIERCE, Dept. of Environmental Science and Engineering, Florida Institute of Technology, Melbourne 32901. Between June and December (1982), three man-made saltwater ponds were used in a shrimp culture project involving sewage enrichment. To investigate the effect of chlorophenol contamination in such a system, one pond received sewage and pentachlorophenol (PCP) through the entire experiment; a second pond received sewage and PCP for 89 days, followed by a 71 day decontamination period; the third pond received neither sewage nor PCP. The concentrations of PCP in the water column, sediments, and shrimp were measured by solvent extraction and gas chromatography. The concentration of PCP in the water, sediments, and shrimp are compared and the persistence of PCP in the water and sediments is evaluated.

5:00 pm ENV-134 Role of Sediments in Buffering Lake pH. R. W. OGBURN, III, L. A. BAKER*, P. L. BREZONIK*, AND E. S. EDGERTON, Univ. of Florida, Dept. of Environmental Engineering Sciences, Gainesville, FL 32611, *Univ. of Minnesota, Dept. of Civil and Mineral Engineering, Minneapolis, MN 55455. Sediments from several lakes near Gainesville, Florida were tested for their capacity to neutralize strong acid and base. Significant Acid Neutralizing Capacity (ANC) and Base Neutralizing Capacity (BNC) were found in batch titrations of sediment-water mixtures. Typical results showed a consumption of 6 and 20 μeq H^+/g of sediment over the respective pH ranges 4.9-3.8 and 4.9-3.0. With base additions, 4 and 40 μeq OH^-/g were consumed over the pH ranges 4.9-6.4 and 4.9-8.3. Lake water consumed negligible amounts of H^+ or OH^- over these pH ranges. From 50-60% of ANC was accounted for by ion-exchange processes involving release of Ca^{2+}, Mg^{2+}, and Al^{3+} to the supernatant, while Na^+ and K^+ concentrations stayed nearly constant. These findings indicate that lake acidification may not occur as fast as water chemistry would indicate, but they also suggest that restoration of acidified lakes may be a difficult process.

5:15 pm ENV-135 Identification of the Tidal Mixing Zone and Factors Limiting Productivity with the Manatee River Estuary System, Manatee County, MICHAEL G. HEYL, M. SIMPSON, AND B. MACLEOD, Manatee County Utilities, 18315 Dam Rd., Bradenton, 33508. An 18 month study was initiated in March 1982 to characterize physical, chemical and biological parameters of the Manatee River estuary system. Preliminary results are reported on identification of the tidal mixing zone and identification of the limiting factors affecting productivity. A broad zone of tidal mixing was defined by benthic community distribution, riparian plant distribution, and analysis of salinity variations. This zone was located 14 to 16 kilometers upstream during the wet season and commenced 17 kilometers upstream during the dry season. Regression analysis indicate that this system is not light limited, but appears instead to be nutrient limited. Secchi depths (transparancy) were inversely related to chlorophyll a levels, while higher chlorophyll a levels paralleled the higher nutrient levels found in low secchi waters. This study was funded in part by the Office of Coastal Zone Management.

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 2:15 pm Donald R. Shephard Seminar Building, Gold 2
BUSINESS MEETING: Florida Committee on Rare and Endangered Plants and Animals
L.M. EHRHART, University of Central Florida, presiding

GEOLOGY AND HYDROLOGY

FRIDAY 8:30 am Donald R. Shephard Seminar Building, Red 1
SESSION A
C.J. MOTT, St. Petersburg Junior College, presiding

8:30 am GHY-136 A Revised Facies Anatomy of the Miami Limestone. EVANS, CHARLES C., Univ. of Miami, Fisher Island Station, Miami Beach 33139. Study of a line of borings and exposures in the Miami Limestone reveals the presence and distribution of three distinct depositional facies instead of the previously recognized two. The late Pleistocene Miami Limestone is best divided into three distinct facies: the bryozoan, the bedded, and the mottled facies. The bryozoan facies is confined to the low lying region west of the Atlantic Coastal Ridge and does not, as previously thought, continue eastward underneath the Ridge. The Coastal Ridge in the Miami area is comprised exclusively of the bedded and mottled facies which make up 40 and 60% of the Ridge respectively. These revisions substantially change the depositional history of this unit in that 1) the ooid system originated and grew in place and did not, as dictated by the previous Waltherian model, migrate bankward over the platform interior deposits under the influence of the transgressing sea, and 2) the positive bathymetry of the ooid system was directly responsible for the simultaneous development of the protected, platform interior, deposits of the bryozoan facies.

8:45 am GHY-137 Clay Minerals of Dade County. JON KIM, Department of Geology, University of South Florida, Tampa, FL 33620. Sub-lateritic soils of the eastern Everglades contain chlorite as their only clay mineral component when examined using X-ray diffraction. It appears that the brucite layer of these chlorites has been partially degraded based on theoretical intensities. Further examination of the bedrock in the area (Miami formation) using X-ray diffraction yielded a very similar chlorite species to the sub-lateritic soils. The bedrock chlorite is more crystalline and does not appear to have undergone significant weathering. As the clay fraction is monomineralic, it is probable that the chlorite is in diagenetic equilibrium with the limestone rather than being a simple detrital admixture or a weathering product. Research is currently underway to study the clay mineralogy of the Miami formation using more intensive analytical methods (SEM, atomic absorbtion, XRF, and computer modelling) in order to elucidate the diagenetic history of these clays.

9:00 am GHY-138 The Role of Copper and Zinc in Clay Mineral Structures: ABRAHAM ROSENZWEIG, Department of Geology, University of South Florida, Tampa, FL 33620. Zinc and copper may occupy sites analagous to those of aluminum and magnesium in clay minerals, but their structural roles differ. Zinc forms regular octahedral 6-coordinated groups, whereas copper forms distorted octahedra with two longer ligands (4+2 coordination). Although Cu may substitute for Zn, it generally requires structurally distinct sites if it is an essential component. In the sulfate mineral serpierite, the ratio (4+2) site: (6) site is 5:3; the ratio Cu:Zn is 5.28:2.72. Zinc can form trioctahedral clay minerals such as sauconite (sodium-zinc montmorillonite) and fraipontite (aluminum-zinc kandite). A fraipontite-like mineral with Zn:Cu close to 1.0 has been found. Assuming the requirement of (4+2) sites for Cu this case may represent the limit of Cu occupancy of an octahedral layer without such severe distortion that it cannot fuse with a tetrahedral silicate layer in the normal fashion of kandite clays.

9:15 am GHY-139 Chemical and Mineral Stratigraphy of a Miocene Fullers Earth Deposit: Green Acre Mine, Ocala, Florida. GREG C. PATRICK, RICHARD N. STROM, AND SAM B. UPCHURCH, Dept. of Geology, University of South Florida, Tampa, FL 33620. The Green Acre Mine is located approximately 25 miles NW of Ocala. The mine exposes a series of interlayered clay, sandy clay, clayey sand, and opalized claystone beds, overlain by sands displaying cutans. The outcrop has been sampled at contacts in the interlayered series and at transition zones in the undifferentiated sands. Investigations include bulk and clay mineralogy and chemical analyses of the clays. Preliminary results reveal a complex suite of mineral phases, including: quartzose Magadiite-like chert nodules, sepiolite, apatite, montmorillonites, illite and minor amounts of palygorskite. The intention of the study is to 1) determine which phases, if any, of the mineral suite are detrital versus authigenic in origin; and 2) define the range of chemical parameters limiting the formation, and co-existence, of the authigenic minerals.

9:30 am GHY-140 A Depositional Model for the Citronelle (Plio-Pleistocene) Sands, Interlachen Karstic Highlands, Putnam County, North Central Florida. Barry C. Kane Department of Geology, University of Florida, Gainesville, FL 32611
The depositional history of the Citronelle sands in North Central Florida is related to climatic and sea level fluctuations during the Plio-Pleistocene. Sand body geometry, paleocurrent data, and physical sedimentary structures visible in quarries suggest a prograding shoreline in the Neogene. Many of the primary sedimentary structures were formed by complexly varying hydrodynamic conditions and cannot be directly related to one specific process. Stratigraphic position and facies relationships suggest some general environmental restrictions which range from fluvial to intertidal to shallow sublittoral.

9:45 am BREAK

10:00 am GHY-141 The Paleogeographic Distribution of the Endolithic Bivalve, *Lithophaga*, through the Cenozoic. DEBRA K. KRUMM AND DOUGLAS S. JONES, Department of Geology, University of Florida, Gainesville, FL 32611. Stemming from observations of specimens of the bivalve *Lithophaga sp*. which occur in the Eocene Ocala Group of Florida, a literature survey was taken of the paleogeographic distribution of this genus, emphasizing Cenozoic North America. From their origins in the Cretaceous to the present, these mytilid borers have spread throughout the low-latitude world exploiting such diverse hard substrates as corals, shells and even volcanic tuffs. Members of the genus *Lithophaga* have been present in southeastern North America from at least the Eocene to the Recent. In the Caribbean and southern Florida today there are four common species. These bear a close resemblance, both anatomically and ecologically, to specimens dating as far back as the Miocene in Florida. The Eocene lithophagids, however, appear more closely linked with European species. The formation and subsequent breakup of the Tethyan seaway is believed responsible for the disjunct distribution of the various species of Floridan *Lithophaga*.

10:15 am GHY-142 Review of testaceans cited in foraminiferal papers. HAYDEE LENA-HERNANDEZ, Florida Institute of Technology, Melbourne, Fl. 32901. Testaceans cited in foraminiferal papers were reviewed. Only 26 of the many analyzed taxa were valid. It was determined that 11 species reported as agglutinated foraminifers were in fact testaceans. Of these, *Leptodermella excentrica*, *L. vadencens*, *L. variabilis*, *Millettella spinata*, *Proteonina oceanica*, *P. prolixa*, and *Urnulina rotundata* are synonymous with well-know testaceans species; *Leptodermella salsa*, *Pseudoarcella arenata*, and *Urnulina compressa* are valid species and are now placed in testacean genera (*Cyclopyxis salsa*, *C. arenata* and *Centropyxis compressa*); and *Millettella elongata* is renamed *Centropyxis rioplatensis*. The testaceans found with fossil and living foraminifers are typically from recent continental, aquatic environments. Their presence in marine sediments may be due to runoff from freshwater bodies (rivers, lakes, etc.) or due to coastal sediment movement.

10:30 am GHY-143 Spiny Megaspores from Mississippian Lycopods. MICHELLE J. BALLARD, SHEILA D. BRACK-HANES AND CHARLES J. MOTT, Eckerd College, St. Petersburg, FL 33733 and St. Petersburg Junior College, Clearwater, FL 33733. The Mississippian megaspore, *Echitriletes echinoides*, described by Chaloner in 1954 from isolated spores, has been attributed to the lycopod sporophyll, *Lepidostrobophyllum fimbriatum* (Kidston) Allen. New specimens of *Echitriletes* spores have been found isolated as well as in sporangia of sporophyll compressions discovered in Mississippian strata of Georgia. The Georgia sporophylls, however, are not *Lepidostrobophyllum fimbriatum*, but appear smaller with a distinctively narrow lamina that has entire (smooth) margins. Therefore, we believe that the spore *Echitriletes echinoides* may have been produced by more than one kind of lycopod during the Mississippian.

10:45 am GHY-144 A Mississippian Lycopod Cone from Georgia. THOMAS R. LANE AND SHEILA D. BRACK-HANES, Eckerd College, St. Petersburg, FL 33733. Lycopod cone fragments have been discovered in the late Mississippian (Chesterian) rocks of Northwest Georgia. General morphological features of the cone are discussed and the new material is compared with similar lepidodendroid cones of equivalent age.

FRIDAY 11:00 am Donald R. Shephard Seminar Building, Red 1
BUSINESS MEETING: Geology and Hydrology Section
D.P. SPANGLER, University of Florida, presiding

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 2:30 pm Donald R. Shephard Seminar Building, Red 1
SESSION B
D.P. SPANGLER, University of Florida, presiding

2:30 pm GHY-145 Middle Eocene Seagrass Compressions from the Avon Park Limestone of Florida. ALICE PERUSSAULT AND SHEILA D. BRACK-HANES, Eckerd College, St. Petersburg, FL 33733. Fragments of a seagrass resembling the turtle grass, Thalassia, were reported by Dixon in 1972, to occur as compressions in the Avon Park Limestone. In the present study, a comparison is made between the Eocene seagrass and other seagrasses both fossil and living.

2:45 pm GHY-146 The Florida Basement: Implications for Tectonics Models. DOUGLAS L. SMITH, Dept. Geol., Univ. Florida, Gainesville, FL 32611. The long-realized but poorly-detailed distribution of undeformed and unmetamorphosed Ordovician to Silurian sandstones and shales underlying Coastal Plain rocks in north central Florida precludes the existence of a late Paleozoic plate suture and associated deformation in this area. An Afro-South American origin for the Florida basement is suggested by Pan-African ages of the granitoid batholith beneath the central part of the peninsula and is corroborated by Afro-South American faunal affinities among fossils in the Paleozoic sedimentary sequence. The absence of Alleghenian deformation in the Florida basement constrains plate interactions to a transform boundary between the Southern Appalachians and the Ouachitas, thereby fixing the collisional stresses inboard of Florida in the Ouachita Mountains. The complex sequence of early Mesozoic volcanic rocks comprising the basement of south Florida suggests a period of continental rifting originating in the South Florida - Bahamas Platform region and coeval with the initial opening of the present day Atlantic Ocean.

3:00 pm GHY-147 Bimodal Volcanism in the Mesozoic Basement of South Florida: Evidence for a Mantle Plume. PAUL A. MUELLER, Geology Dept., University of Florida, Gainesville, Florida 32611. Wells drilled to basement in southern peninsular Florida invariably encounter basaltic and/or rhyolitic volcanic rocks of late Triassic or early Jurassic age. Elsewhere in eastern North America volcanism at this time is exclusively basaltic and commonly associated with the initial opening of the present-day Atlantic Ocean. The existence of substantial quantities of rhyolitic rocks in southern Florida, however, necessitates a more complex tectono-magmatic environment. Chemical and isotopic analyses of selected basaltic and rhyolitic rocks suggest the rifting in southern Florida may have been associated with a mantle plume. If so, this has important tectonic implications for the mode of continental separation in this region and the configuration of the pre-Mesozoic basement of the western Gulf of Mexico.

3:15 pm GHY-148 Origin of the Epeirogenic Uplift of Plio-Pleistocene Beach Ridges in Florida and Development of the Florida Karst. NEIL D. OPDYKE, D.P. SPANGLER, D.L. SMITH, D.S. JONES and R.C. LINDQUIST, Dept. of Geology, Univ. of Florida, Gainesville, Fl. 32611. Marine fossils of Pleistocene age are known to occur in beach ridges near the border of northern Florida and southern Georgia at elevations of between 42 and 49 m above mean sea level. The $\delta^{18}O$ curve for the Pleistocene and Late Pliocene shows no evidence of the massive melt off of glacial ice which would be required to raise sea level to these elevations. Therefore, Florida must have been uplifted epeirogenically during the Pleistocene. Erosion is taking place in Florida as a result of dissolution of limestone by ground water. Measurement of dissolved solids in Florida's springs demonstrates that the karst area is losing a minimum of 1.2×10^6 m^3/y of limestone through spring flow, the equivalent of one meter of limestone every 38,000 years causing an uplift of the north central part of the Florida peninsula of at least 36 meters through isostatic rebound during the Pleistocene.

3:30 pm GHY-149 Interpretation of Buried Topography in Okefenokee Swamp, Georgia Using Vegetation Zones Mapped from Color-Infared Photography. JOE R. WADSWORTH, JR. Department of Geology, University of South Florida, Tampa, FL 33620. Boundary configuration and overall shape of vegetation zones in Okefenokee Swamp, mapped previously using color-infared photography and field surveys, were used to delineate sets of arcuate features. Shape, distribution and cross-cutting relationships of these features strongly resemble recent geomorphic features associated with Carolina bays, and are thought to reflect eroded sand ridges and adjacent depressions, buried below the present swamp surface. A major phase of shallow oriented lake formation preceeding development of the present day swamp is implied. Physical controls on zones include topography and hydroperiod as well as substrate composition, modified by stages of successions. Initial probing transects to determine peat thicknesses support interpretations of sub-peat topography and further transects are planned.

3:45 pm BREAK

4:00 pm GHY-150 Slope Morphology in the Foothills of the Rampart Range, Colorado. ROBERT O. CLARK, University of South Florida, Tampa, FL 33620. One idea that persists among some geomorphologists suggests that hillslopes sculptured in regions of identical lithology and climate evolve similar profiles. To shed some light on this theory, a profile study was conducted in two adjacent foothill areas of the Colorado Front Range. The study areas (A and B) are semiarid and support an open coniferous woodland. The dominant lithology is a weakly indurated arkosic conglomerate of Paleocene age which has been fluvially dissected into a series of linear ridges. Area A is dominated by valley sides that are convexo-concave while Area B exhibits profiles that are distinctly concave. The isolated ridge structure of Area A is essentially an erosional remnant detached from the larger drainage system of the Rampart Range. In this restricted drainage basin, slopes are only rarely affected by channeled water flow. By contrast, slope evolution in Area B is controlled by ephemeral streams emanating from the adjacent mountains. Actual profiles thus reflect a complex set of gradational mechanisms associated with the erosional environment.

4:15 pm GHY-151 LASERTRACE: A New Method for Geologic Sampling. A. RICE, Ocean Engineering, Florida Inst. of Tech., Melbourne, FL 32901. Sparse sampling of geologic units on orders of meters will miss significant elemental variations that occur over centimeters and are vital to estimations of Soret Fractionation. Fine sampling can be obtained by cleaning and comminuting a section of geologic unit, the resultant powder being taken up on scotch tape laid down on the section. In the lab the tape is advanced past a laser which ablates samples from the adhesive. The vaporized sample is brought up in an argon gas stream into an RF-ICP wherein abundances of 25 elements may be ascertained through a polychromator. Sampling may be done as close as every 3mm. Results are provided for some volcanic units including several thousand elemental assessments along 30m in the vertical of a section of Crater Lake Ash. Infered Soret coefficients for the field compared with laboratory efforts show similar trending.

4:30 pm GHY-152 Subsurface Analysis of Duval County, Florida. DAVID E. BUTLER and DANIEL P. SPANGLER, Geology Department, University of Florida, Gainesville, Fl 32611. A subsurface analysis of Duval County was done using geologic, driller's and geophysical logs. The geologic and driller's logs were used primarily for analysis of the Ocala Limestone and Avon Park Limestone. The geophysical logs (electric and gamma) were used for analysis below the Avon Park Limestone by noting electric and radiation patterns, and were broken into 5 electric and 3 radiation zones. The top of each zone and its corresponding thickness were mapped for the study area. All of the structure contour maps are structurally high in the western and eastern portion of the study area and structurally low in the center. There are several linear anomalies that appear on the structure contour maps. Three of these anomalies are considered faults, but there are other possibilities for their origin.

4:45 pm GHY-153 A Hydrogeochemical Depiction and Analysis of the Floridan Aquifer in North Central Florida Utilizing Data from Diverse Sources. MARK SILVERMAN AND DANIEL P. SPANGLER, Dept. of Geology, University of Florida, Gainesville, FL 32611. Data satisfying certain minimal criteria can be compiled from various government agencies and public water supply utilities and then utilized to elucidate the hydrogeochemistry of an aquifer so that a monitoring program can be established. To show this, a study was made of North Central Florida. Indications of well depth and depth to the bottom of the well casing were necessary for site selection. Hydrogeochemical maps were produced by computer (Surface II program) and were gradationally shaded for fourteen major ions in the Floridan aquifer. Maps of well depth were similarly made. Specific conductance, alkalinity and calcium exhibited the strongest correlation to each other, and were most consistent temporally. Six other parameters closely reflected the nature of sediments overlying the aquifer. Some parameters also showed the effect of well depth; chloride also reflected proximity to the salt water interface. Nitrate was highest in unconfined areas.

5:00 pm GHY-154 Aerial Survey of Selected Karst Features in Central and Northern Florida. FRANK B. KUJAWA, Dept. of Chemistry and Geology, University of Central Florida, Orlando, FL 32816. Three-screen aerial panoramas will be used to compare Karst features in selected areas of Orange, Lake, Polk, Columbia, and Hamilton counties. An update on the large Winter Park Sinkhole will also be provided.

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

MEDICAL SCIENCES

FRIDAY 8:30 am Donald R. Shephard Seminar Building, Gold 2
D.A. NICKERSON, University of South Florida, presiding

8:30 am MED-155 Histopathologic Perivascular Alterations in Cerebral Parenchyma Secondary to Acute Traumatic Intracranial Hypertension Engendered by Acute Epidural Hematoma. CHARLES J. GUTIERREZ, Respiratory Therapy Program, University of Central Florida, Orlando, Fl., 32816. A case study was conducted of a comatose head trauma patient. CAT scans revealed a large bi-convex hematoma resulting from trauma to the right middle meningeal artery. A review of the experimental literature produced a flow chart which seemed to explain the patient's clinical manifestations. The viability of the experimental data appears to have been established insofar as it elucidated possible pathophysiologic mechanisms underlying the patient's clinical status. The hematoma apparently induced acute intracranial hypertension rendering the neural parenchyma ischemic according to the No-Reflow Phenomenon. Astrocyte and Oligodendroglial cell ischemia in the brainstem's vasomotor and respiratory centers may have been a key event resulting in compromised cardiopulmonary function in this patient.

8:45 am MED-156 Evidence for the Existence of a Sexually Dimorphic Nucleus in the Mouse Brain. Peter R. Mouton and Gary W. Arendash, Dept. of Biology, University of South Florida, Tampa, Florida 33620. The mouse preoptic-anterior hypothalamic area was examined to determine if a nucleus of neuronal cell bodies exists and, if so, whether or not the volume of such a nucleus is sexually dimorphic. Adult mice from two different strains were used; ICR white mice and C57BL/6 black mice. Microscopic examination of histologically prepared brain sections revealed an intensely staining nucleus of cells located within the anterior hypothalamic area. An ensuing analysis of this nucleus' volume indicated a clear sexual dimorphism. Nuclear volumes for the males were 70% and 71% larger than those of females for the ICR and C57BL/6 strains, respectively. It is suggested that this nucleus be termed the Sexually Dimorphic Nucleus of the Anterior Hypothalamic Area (SDN-AHA).

9:00 am MED-157 A Comparative Study of the Cells in the Semicircular Canal Endorgans (Cristae Ampullares) in Young and Old C57BL/6J Mice. R.J. HUNTSINGER, G.M. COHEN AND J.C. PARK, Dept. Biological Sciences, Fla. Institute of Technology, Melbourne, FL 32901. Aging organisms commonly experience balance problems. In humans, the effects of age on inner ear cells are difficult to separate from those caused by illness and drug therapies. In contrast, laboratory mice can be evaluated on the basis of senesence alone. We compared the cristae ampullares of young (4½ mo) and old (26-27 mo) C57BL/6J mice. In contrast to other reports on the effects of age on the vestibular portion of the inner ear, we found no evidence at the light microscopic level of cellular degeneration. Surprisingly the cytology of the hair cells, supporting cells, and sensory nerve terminals is similar to that seen in the young mouse. We found no evidence of sensory cell loss in any of the ampullae we examined.

9:15 am MED-158 Loss of the Chick's Equilibular Function caused by Streptomycin and Gentamicin. COHEN, G.M. AND J.C. PARK, Dept. Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901. Streptomycin and gentamicin caused progressive losses of equilibular functions in chicks. Antibiotics were administered by daily subcutaneous injections in the breast. Equilibrium was monitored by strain gauges attached to the perch. Normal chicks swayed back and forth in a regular, pendulous motion while balancing on the perch. By comparison, intoxicated chicks swayed in an irregular exaggerated manner. Moreover, chicks slowly tilted forwards, backwards, or to the sides before detecting their own body position and then abruptly corrected themselves with overcompensating movements. Intoxicated chicks did not clutch the perch as tightly as normal birds, contributing to the slipping movements of their feet. Gentamicin impaired equilibular function with about 4X the potency as streptomycin. (The gentamicin (Garamicin) was kindly supplied by Schering Corp.)

9:30 am MED-159 Cloned A-549 Cells as a Model for the Synthesis of Human Lung Surfactant "Apoproteins". S.D. BUMGARNER, S.A. SHELLEY, J.E. PACIGA, N.E. LOWELL AND J.U. BALIS, Dept. of Pathology, Univ. of South Florida, Tampa 33612. A-549 cells, originally derived from a human lung carcinoma, resemble alveolar type II epithelial cells which in normal human lung synthesize and secrete surfactant. A-549 cells contain cytoplasmic inclusions similar to lamellar bodies, the surfactant storing organelles of type II cells. Single cell clones from A-549 were established as cell lines, then examined for the presence of lung surfactant proteins(M.W.>400,000)using immunoperoxidase techniques. One clone line was consistently negative, whereas the remainder exhibited varying proportions of specifically labeled cells. All cloned lines contained lamellar bodies and were ultrastructurally similar. These results indicate that A-549 cells originate from type II epithelium but manifest variable expressions of differentiated cell function. These clones may be useful in studying normal and altered biosynthesis of human surfactant proteins. Supported in part by NIH HL29498.

9:45 am MED-160 Development of Morphological Forms of *Basidiobolus* and *Conidiobolus* through Nutritional Enhancers. VIRGINIA G. BAKER, BIENVENIDO G. YANGCO, Department of Medicine, Division of Infectious and Tropical Diseases, and DIANE TE STRAKE MERNER, Department of Biology, University of South Florida, Tampa, FL 33620. In the preparation of antigenic inocula, five species of *Basidiobolus* and two species of *Conidiobolus* were grown in five biochemically distinct broths; four of which repeatedly produced separate and distinct morphological variations of each of the stock isolates. Through the manipulation of carbohydrate and asparagine enhancers, the nitrogen base broth readily supported active and rapid development of each of the distinct forms; one of which represented a sexual population approaching 90%.

10:00 am BREAK

10:15 am MED-161 Murine Immunity Following Intratracheal Infection with *Histoplasma capsulatum*. PHILIP FAIRCLOUGH and DEBORAH A. NICKERSON, Department of Biology, University of South Florida, Tampa, FL 33620. The influence of intratracheal (it) or intravenous (iv) inoculation with *H. capsulatum* yeast cells on *in vitro* immune potential has been determined in C57Bl/6 mice. Our results indicate a significant level of splenic blastogenesis to heat-killed *H. capsulatum* (HK-Hc), one week following it inoculation. In comparison, responses to HK-Hc were not detected until 3 weeks after iv *H. capsulatum* infection. The presence of HK-Hc reactive cells in iv inoculated animals appears to correlate with the loss of splenic suppressor cell populations. Examinations of nonspecific immune responses, i.e. mixed lymphocyte reactivity to alloantigens and antibody formation to sheep red blood cells, during it *H. capsulatum* infection shows a significant but temporary depression of these responses at 1 week. Lastly, this early immune depression during it infection is not mediated through the generation of suppressor cells. Supported in part by NIH AI 17750.

10:30 am MED-162 *Brugia pahangi* (Nematoda: Filarioidea) in Nude and Normal Mice. ANN C. VICKERY AND ALBERT L. VINCENT, University of South Florida, College of Medicine, 13301 N. 30th St., Tampa, FL 33612. Congenitally athymic nude (nu/nu) C_3H/HeN mice are susceptible to infection with *B. pahangi*. In contrast, euthymic heterozygotes (+/nu) and thymus-grafted nudes (T-nu/nu) resist infection. Examination of immune responses to parasite antigens after inoculation with 50 larvae showed that +/nu and T-nu/nu but not nu/nu mice produce high titers of specific IgG and IgE as well as strong delayed hypersensitivity footpad swelling responses to antigen. In addition, +/nu mice exhibit eosinophilia (25%) which peaks 3 weeks post-inoculation. These responses, which are potentiated by reinfection, suggest that protective immunity is thymus-dependent. However, comparison of lymphatic pathology in +/nu and nu/nu mice suggests that some elements of filarial lymphatic inflammation, such as lymphangiectasis and fibrosis, are independent of cell-mediated immune responses.

10:45 am MED-163 Utilization of a Microhemagglutination Antibody Test for *Treponema pallidum* (MHA-TP) with Sera from Patients with Collagen Disease. DENO KAZANIS AND JACK FRANKEL, Tampa Regional Lab., 1115 E. Kennedy, Tampa 33601. In comparing newly developed treponemal serological tests for syphilis with fluorescent treponemal antibody absorption (FTA-ABS) test, we investigated the problem of false positive results. Evidence has been presented that sera derived from patients with systemic lupus erythematosus and other collagen diseases upon examination in the FTA-ABS test may react with uncharacteristic fluorescence (e.g., "beading" effect). Thus, the potential exists for incorrectly reporting the true nature of the reaction. We examined sera from patients with lupus in the MHA-TP test (SERA-TEK, Ames Division, Miles Laboratories) and by the FTA-ABS technique. Of 43 such sera, in the FTA-ABS technique, 9 showed uncharacteristic fluorescence; none of these 43 serum specimens showed any reactivity in the MHA-TP test. Among 120 sera examined from patients without any history of collagen disease, there was no significant difference in findings.

11:00 am MED-164 A Novel Corynebacterium Infection in Newly Captured 9-Banded Armadillos. J.A. ZEIGLER[1], S.W. WILLIAMS[1], W.P. VAN ESELTINE[2], A. DHOPLE[1], and E.E. STORRS, Medical Research Institute, Florida Institute of Technology, Melbourne, Fl.[1], and, Department of Medical Microbiology, College of Veterinary Medicine, University of Georgia, Athens, Ga.[2]. The 9-banded armadillo (D. novemcintus) is unique as an animal model for studies of human leprosy. Routine screening of newly captured animals is performed by examining nasal, ear, and buffy coat smears after Gram and Carbofuchsin staining. Recently, three groups of armadillos introduced into the colony were found to have bacteremia involving a pleomorphic, gram positive bacillus of unknown origin. Routine isolation techniques produced a coryneform from blood cultures. A taxonomic profile for identification is now in progress. Supported in part by NIH Contract NOI A192637 and WHO Project #810361.

11:15 am MED-165 Application of ATP Assay to Patient Care in Leprosy. ARVIND M. DHOPLE AND BARBARA HOPP. Medical Research Institute,Florida Institute of Technology, Melbourne, FL 32901.The inability to cultivate Mycobacterium leprae has been a major bottleneck in leprosy research. The only method currently available to determine drug-resistant M. leprae is its transmission to mice. However, this method is time consuming and expensive. Because of ubiquitous distribution and metabolic importance of adenosine triphosphate (ATP), it makes a promising method for quantitating microorganisms during various pathological processes. We have, therefore, initiated an international collaborative study, employing ATP assays, to obtain fast and reliable information on the status of M. leprae harvested from leprosy patients under chemotherapy and identify drug resistant cases in very early stages. Preliminary results show close correlation between ATP content of M. leprae, its viability in mice and drug response of the patient.

FRIDAY 11:30 am Donald R. Shephard Seminar Building, Gold 2
BUSINESS MEETING: Medical Sciences Section
D.A. NICKERSON, University of South Florida, presiding

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

PHYSICAL, ATMOSPHERIC, OCEANOGRAPHIC, AND SPACE SCIENCES

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 9:00 am Donald R. Shephard Seminar Building, Red 1
SESSION A: Chemical Oceanography
J.H. TREFRY, Florida Institute of Technology, presiding

9:00 am PAO-166 Vertical Distribution of Phytoplankton Related to Physical Parameters in Proximity to the Gulf Stream Off Ft. Pierce, Florida. LAWRENCE R. MYERS AND D. R. NORRIS. Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne, FL 32901. Seasonal collections of phytoplankton present at various depths (0, 10, 20, 30 and 35 meters) in the water column were made using a Clarke-Bumpus plankton sampler. Measurements of temperature, salinity, and light were also taken through the water column. Analysis of plankton samples to discern the dominant species with depth was done and the results related to the physical parameters. A subsurface population maximum was found to exist. Chlorophyll a analysis was done to see if the deep population maximum coincides with either or both a chlorophyll a maximum or the thermocline. A possible mechanism involved in the formation of these maxima layers as well as determinations of chlorophyll a per cell will be discussed.

9:15 am PAO-167 Variations of Dissolved Cadmium Levels associated with Short Term Upwellings. GARY N. PETERSON AND JOHN MONTGOMERY, Harbor Branch Foundation, Inc., Rt. 1, Box 196, Ft. Pierce, FL 33450. Three hydrographic stations, 8.1, 17.8 and 28.0 km off the east coast of Ft. Pierce, Fla., were sampled from June 1, 1982 through June 30, 1982. Two upwelling events occurred during this period. The upwellings were characterized by water temperatures $\leq$ 19°C and Nitrate concentrations ranging from 3.0 µM to 12.2 µM. A significant increase in productivity was also recorded during the upwellings. Dissolved Cadmium levels ranged from generally non-detectable (< 12.5 ng/L) between upwelling events to 28.4 ng/L during upwellings.

9:30 am PAO-168 Trace Metals in Plankton from the Mississippi Delta. ROGER B. BEWIG AND JOHN H. TREFRY, Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne, FL 32901. Phytoplankton and zooplankton samples collected off the Mississippi Delta during May and September, 1982, have been analyzed for Mn, Fe, Cu, Zn, Pb and Cd. Metal-free nets and clean-lab conditions were used throughout the study. The Mississippi River, which drains 40% of the U.S., is polluted with particulate Pb and Cd at 2 and 5 times respectively above natural levels. The Mississippi River is therefore an important source of potentially toxic metals to the highly productive waters of the Mississippi Delta. From analyses to date, zooplankton concentrations are: Mn, 4 to 50 ppm; Fe, 120 to 600 ppm; Cu, 7 to 30 ppm; Zn, 70 to 220 ppm; Pb, 0.2 to 3.0 ppm and Cd, 1.0 to 3.4 ppm. These values, along with metal concentrations for particulate and dissolved metals are compared from a biogeochemical perspective.

9:45 am PAO-169 Heavy Metals in Cultured Shrimp. MATTHEW LANDAU, Florida Institute of Technology, Dept. of Oceanography and Ocean Engineering, Melbourne 32901. *Penaeus stylirostris* was cultured in both seawater and in a mixture of wastewater: seawater (1:9). The harvested shrimp taken from the seawater/wastewater ponds had significantly more mercury, and perhaps cadmium in the edible tissue than did the control (seawater) shrimp. Smaller shrimp had significantly more lead and selenium than did larger shrimp. Chromium and copper levels did not vary as a function of either culture scenario or size. *P. vannamei* cultured under similar conditions depurated mercury from their edible tissue as they grew, however, in the non-edible portion of the shrimp, mercury was either concentrated or depurated as a function of the metal's concentration in the detritus on the pond's bottom.

This research was supported by an NSF grant no. DAR-8023060.

10:00 am PAO-170 The Behavior of Fly Ash Derived Arsenic in Seawater. VINCENT T. BRESLIN. Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne 32901. Fly ash in contact with seawater can exhibit either acidic or alkaline tendencies depending upon the soluble elemental composition on the surface of the fly ash particle. The acidic ashes were shown to leach a higher percentage of arsenic (16.9%) than the more alkaline ashes (8.2%). During these leaching studies in seawater, arsenic was found to leach in both the pentavalent and trivalent oxidation state. The pentavalent state was predominant, comprising 77% of the arsenic initially desorbed. The solubility of arsenic in seawater was utilized to assess the possible impact of the ocean disposal of fly ash. Calculations indicate that natural levels of arsenic in the water column would not be significantly increased based upon a single ocean dumping event.

10:15 am BREAK

10:30 am PAO-171 Groundwater Seepage Velocities in Estuaries: Effects of Sediment Size and Interstitial Phosphate Concentrations. CARL F. ZIMMERMANN, J. MONTGOMERY AND P. CARLSON, Harbor Branch Foundation, Inc., R.R. 1, Box 196, Ft. Pierce, FL 33450. Variability in seepage velocities of nearshore areas appears to be due to variations in sediment type. Highest seepage velocities and greatest interstitial phosphate concentrations occur in sandy sediments. Seepage flux accounted for 98% of the combined estimated diffusive and measured seepage flux of interstitial phosphate for nearshore seagrass sediments in the Indian River lagoon.

10:45 am PAO-172 Manganese and Iron Chemistry of Mississippi River Delta Pore Water. THOMAS W. VETTER, JOHN H. TREFRY, AND SIMONE METZ, Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne 32901. High sedimentation rates on the Mississippi River Delta lead to large scale reduction/dissolution of Fe and Mn oxides in the anoxic Delta sediments. As a result, high pore water concentrations of Fe and Mn (up to 40 mg/liter) are measured in the top 2 to 10 cm of the sediment column. With depth, concentrations decrease to "equilibrium" values. Relative to Mn, the pore water Fe maxima occur deeper in the sediment column because of differences in redox chemistry. Nearshore, the sediments are depleted in solid-phase Mn and Fe relative to the river suspended matter. This depletion is due to diffusive losses of the dissolved species to the overlying water. Offshore, precipitation of upwardly diffusing dissolved Mn leads to solid-phase Mn enrichment in the surficial oxic sediment. Phosphate and alkalinity, which exert important thermodynamic controls on Fe and Mn solubilities, also increase with sediment depth at values up to 200 μM and 15 meq/liter respectively.

11:00 am PAO-173 The Distribution and Provenance of Trace Metals in Gulf of Mexico Sediments. B. KEVIN WOOD AND JOHN H. TREFRY, Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne 32901. The regional distribution of Fe, Cr, Ni, and Pb in surficial shelf sediments of the Gulf of Mexico has been contoured using CALCOMP computer techniques. CALCOMP offers a basic contouring routine in which trend-surface analysis was implemented. Statistical analyses were also applied to the data to identify important geochemical variables that control the observed trace metal patterns. These variables include grain-size, carbonate content, and clay mineralogy. Spatially, the metals range from very low concentrations in the sediments of the west Florida shelf to highest values on the Mississippi Delta and south Texas shelf. Intermediate concentrations are interspersed between these areas. Observed metal contour patterns are referenced to suspended matter from important Gulf rivers to ascertain metal provenance. The seaward extent of sediment/metal transport serves as an important factor in predicting the fate of riverine pollutants.

11:15 am PAO-174 Characterization of Hydrocarbons in Sediment and Organisms from Charlotte Harbor Estuary. ROBERT BROWN, RICHARD PIERCE AND SHAWN MURPHY, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. Hydrocarbon concentration and composition in sediment and organisms (oyster, shrimp, crab, mullet and trout) have been obtained from representative sites throughout the Charlotte Harbor estuarine system. These data show that most of the study areas are relatively free from petroleum contamination. However, certain sites, "hot spots", do show definite petrochemical input. These include commercial docking facilities, marinas, and residential development canals. Continuing studies intend to provide information on the source and extent of petroleum contamination within these areas.

11:30 am PAO-175 New Methodology in Taking Undersea Geologic Samples. D. CLAYTON and W. CZVEKUS, Harbor Branch Foundation, Ft. Pierce 33450; A. RICE, Ocean Engineering, FIT, Melbourne 32901. Maneuvering, ballasting, & trim difficulties attend sampling of undersea geologic units with deep submersible research vehicles. To overcome these difficulties, a rapid procedure to sample large areas of subsea geology is under development (at Harbor Branch Foundation) which employs an extension of the submersible which cleans and comminutes the surface, the resultant particulate taken up on rolls of surgical tape which are sealed with teflon. In the lab, the teflon is stripped, the tape advanced past a laser which ablates the sample, the vapor of which is brought up into an RF-ICP where abundances of 25 elements are determined with a polychromator. Several thousand samples a day may be processed by this procedure. Results for units ashore will be given (e.g., analyses of 3000 points along a 30m vertical section of tuff).

SATURDAY 11:45 am Donald R. Shephard Seminar Building, Red 1
BUSINESS MEETING: Physical, Atmospheric, Oceanographic, and Space Sciences Section
J.H. TREFRY, Florida Institute of Technology, and J.W. SHELDON, Florida International University, presiding

SATURDAY 1:30 pm Donald R. Shephard Seminar Building, Red 1
SESSION B: Physical Oceanography and Physics
J.W. SHELDON, Florida International University, presiding

1:30 pm PAO-176 Topographic Control of Mixing in Stratified Estuaries. RONNAL P. REICHARD, Florida Institute of Technology, Melbourne 32901. Changes in topography cause convective accelerations in estuary currents. These accelerations intensify current shear and decrease the dynamic pressure. The increased shear leads to a decreased Richardson number, indicating an area of decreased stability. The lowered dynamic pressure is balanced by the formation of standing internal waves. The upstream face of these waves is in the area of accelerating flow, and the pycnocline is rising into the high shear zone, resulting in increased mixing. The downstream face is in an area of decelerating flow, and the pycnocline is falling below the high shear zone, resulting in little or no mixing. Thus areas of relatively high and low mixing occur due to changes in topography.

1:45 pm PAO-177 Computer Simulations of Wind-driven Currents in Coastal Lagoons. NED P. SMITH, Harbor Branch Foundation, Rt. 1, Box 196, Fort Pierce, Florida 33450. A 43-day time series of windstress and sub-surface current is used to verify numerical simulations of wind-driven flow along the axis of the Indian River lagoon, on South Florida's Atlantic coast. Nontidal long-channel motion during May and June of 1980 shows low-frequency alternations which are highly correlated with the long-channel component of the windstress vector. Freshwater outflow seems to have been a minor component of the current during this time. With a calibrated model, a one-year windstress record is used to simulate long-channel flow at both near-surface and near-bottom levels over an extended period of time. Calculations suggest both bursts of wind-driven flow and periods of nearly slack water. Results may be important in water quality investigations.

2:00 pm PAO-178 An Investigation of the Relationship between Microseisms and Ocean Waves. KENT K. HATHAWAY AND S. L. COSTA, Humboldt State Univ., Arcata, CA 95521 and Florida Inst. of Tech., Melbourne 32901. A field investigation to simultaneously record microseisms and ocean waves was carried out in northern California. Five data sets were obtained between June 1980 and February 1982. Ocean wave data were collected by an offshore wave-rider operated by the State of California and the Corps of Engineers. Microseismic data were obtained from a long period vertical seismometer operated by the National Weather Service. Inferred wave heights, determined from seismometer signals, were compared to actual wave heights in order to evaluate the seismometer as a land based wave data collection system. Ocean wave spectra were compared to the microseismic spectra to investigate the occurrence of primary and secondary microseisms. A relationship between long period (primary) microseisms and tidal elevation was observed. Further investigations are planned at coastlines with different characteristics. Data will be obtained initially on the east coast of central Florida.

2:15 pm PAO-179 Daily Heat Energy Budget on the Little Bahama Bank, Northwest Providence Channel: Summer Conditions. ELIZABETH A. SMITH, Harbor Branch Foundation, RR1, Box 196, Ft. Pierce, FL 33450. Hydrographic & meteorological records were collected hourly over an 8-day period in the summer of 1982. The data are modeled to describe the local air-sea energy exchanges and, ultimately, the heat budget of the Little Bahama Bank in the Northwest Providence Channel. Presumably, deep ocean water floods onto the bank; an average of about 7 m deep. This cooler water mass from depth temporarily residing on the bank will undoubtedly affect the flux of heat energy in this region over diurnal & semi-diurnal time scales. A numerical model utilizes empirical relationships between the hydrographic and meteorological variables to evaluate hourly insolation, back radiation and latent & sensible heat fluxes. Preliminary results indicate heating on the bank by insolation to be in approximate balance with cooling by evaporation, outgoing longwave radiation & sensible heat fluxes. Advective heat fluxes are also being modeled to explain further the observed residual heat fluxes.

2:30 pm PAO-180 A Study of Energy Balance Models in Sebastian Inlet. FRED O. DAVIS, Florida Institute of Technology, 150 West University Boulevard, Melbourne, Florida 32901. Most energy balance models for tidal inlets use a linearized version of the Navier-Stokes equation. Three different models are being applied to Sebastian Inlet. One model uses average values for current velocity and energy losses due to friction in the inlet. The other two models analyze instantaneous energy balances. The models are compared with field data and each other to determine their applicability.

2:45 pm PAO-181 The Optimization of Cross-sectional Area for Tidal Inlets with Biased Discharge. STEVEN L. COSTA, F.O. DAVIS, JR. AND C.F. ALLEN, Florida Inst. of Tech., Melbourne 32901 (1,2) and Pacific Gas and Electric Co., 77 Beale Street, San Francisco, CA 94106 (3). A technique to determine the optimum flow area of a tidally driven inlet-bay system with a constant discharge from a secondary outlet is considered. For the purposes of this presentation, optimum conditions represent those which minimize the transport of sediment into the entrance channel. Depth of flow is considered the primary variable with inlet width considered fixed. Two solution techniques for the gradually varied steady flow equations of a simplified inlet-bay system are used and compared. Sediment transport calculations are based on empirical relations derived from flume and river data. An example utilizing a very small system with a constant flood current bias is considered. For the example case the flood bias is a significant portion of the total tidal flow and represents a cooling water supply for an electrical power generating plant. Extensions to more general cases are indicated.

3:00 pm BREAK

3:15 pm PAO-182 Neutral and Charged Current Inclusive Neutrino Reactions in ^{12}C, S.L. MINTZ and D. KING, Dept. of Physical Sciences, Florida International University. Calculations of the cross sections for the processes $\nu_\mu + {}^{12}C \rightarrow \nu_\mu + X$ and $\nu_\mu + {}^{12}C \rightarrow \mu^- + X$ will be presented. The role of these reactions in the search for neutrino oscillations and the current status of other neutrino oscillation experiments will be discussed.

3:30 pm PAO-183 A Model for Haidinger's Brushes. RICHARD A. BONE AND JOHN.T. LANDRUM, Department of Physical Sciences, Florida International University, Miami, Florida 33199. The linear dichroism of the carotenoid pigment lutein may be demonstrated by introducing it into a stretched, transparent, polymer film. Lutein is probably the macular pigment, found in the central region of the human retina, and its dichroic properties may account for the formation of the polarization figure known as Haidinger's brushes. This hour-glass shaped figure may be explained with the aid of a model which requires the ordered orientation of lutein molecules with respect to the eye's visual axis. Such orientation is feasible if the molecules are incorporated in the bilipid components of the nerve fiber membranes of Henle's layer, these fibers being radially aligned with respect to the visual axis. The function of lutein within the membranes may be to protect them from photooxidation.

3:45 am PAO-184 Dynamics Explorer Measurements of Soft Particles Over the Earth's Polar Caps. JAMES R. SHARBER, Dept. of Physics and Space Sciences, Florida Institute of Technology, Melbourne, 32901. J.D. WINNINGHAM, Space Physics Dept. Southwest Research Institute, San Antonio, TX 78284. As a satellite makes a transpolar pass, it makes two crossings of the ring-shaped region of auroral emissions known as the auroral oval. It is along this oval that the brightest auroras occur. The region poleward of the oval, the polar cap, also contains auroras although they are often subvisual. This paper will present measurements of the particles which cause these auroras. The measurements were made by the Low-Altitude Plasma Instrument on the Dynamics Explorer 2 Satellite, a NASA low-altitude polar orbiter launched in August, 1981. Particles over the polar cap are usually soft electrons (a few hundred eV) which give rise to optical emissions at 6300 Å (the auroral red line). A comparison will be made between particle measurements from DE-2 and optical measurements of 6300 Å intensity made at Thule, Greenland.

4:00 pm PAO-185 Markarian 320: Spectroscopic Identification of a Hot White Dwarf Among QSO Candidates. TERRY D. OSWALT AND BRADLEY M. PETERSON, Dept. of Physics and Space Sciences, Florida Institute of Technology, Melbourne 32901 and Dept. of Astronomy, The Ohio State University, Columbus, OH 43210. Mk320 is one of a small number of possible quasi-stellar objects (QSOs) exhibiting strong ultraviolet continua tentatively identified as a white dwarf by Wills and Wills (1974, Mon. Not. R. Astr. Soc. 167 79p) from photographic spectra obtained under poor observing conditions. Image Dissector Scanner (IDS) spectra obtained with the OSU 1.8m telescope confirm that Mk320 is a hot white dwarf with prominent hydrogen absorption lines. We present temperature and gravity estimates which indicate that Mk320, though certainly not a QSO, may be of interest to other observers.

4:15 pm PAO-186 The Gravitational "Slingshot" Effect. RUSSELL PATERA, Department of Physical Sciences, Florida International University, Tamiami Trail, Miami, Florida 33199. The transfer of energy and momentum to a spacecraft from a celestial body is examined. The exact analytical solution of the general problem is obtained. The solution was obtained in momentum space rather than in configuration space to reduce computational effort and elucidate the process. It is found that a spacecraft can significantly increase its speed by extracting kinetic energy from a moving celestial body. The effect has already been used in the two voyager missions.

4:30 pm PAO-187 Bohr Quantization of Newtonian Gravitational Systems, JOHN W. SHELDON, Dept. of Physical Sciences, Florida International Univ., Miami, FL 33199. A common exercise in the study of elementary quantum mechanics is to apply Bohr quantization to a gravitational orbit such as the earth-moon system or the interaction of two neutrons. A systematic analysis of such systems over the full size range from microscopic to macroscopic will be presented. For this purpose it is convenient to give the radius of the first Bohr orbit as $r_B = r_o(N_1 + N_2)/(N_1N_2)^2$ where N_1 and N_2 are the number of nucleons in each of the interacting bodies and $r_o = 8.6 \times 10^{54}$m.

SCIENCE TEACHING

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 1:15 pm Donald R. Shephard Seminar Building, Black 2
M.L. IVEY, St. Petersburg Junior College, presiding

1:15 pm TCH-188 Writing a science fiction story as a science term paper. PANGRATIOS PAPACOSTA, Physics Department, Stetson University, DeLand, Florida 32720. The writing of a story in which the wildest imagination is blended with laws of science, or indeed their violation, is an unorthodox and a creative method by which students can demonstrate understanding and appreciation of their science. The writing of a science fiction story as a physics project has been well received as an interesting alternative to a conventional term paper by non-science majors taking physics at Stetson University. The underlying guidelines for the best use of this kind of project, not only for physics but for all other sciences, will be presented in this paper. Segments from student science fiction stories will be read.

1:30 pm TCH-189 Pinhead Earth. KENNETH E. PERKINS, St. Petersburg Junior College, P. O. Box 13489, St. Petersburg, FL 33733. A demonstrated lecture illustrating the expanse of the universe. The lecture uses varying sized spheres to represent the relative sizes of the sun and the planets and a multicolored string to place them in their relative positions. Ten cent coins and a web of simple strings show the expanse of the galaxies.

1:45 pm TCH-190 Evaluation of a Summer Science Institute. ROBERT C. BIRD, PATRICIA C. MANNING, AND JOHN J. BRENNAN, University of Central Florida, P.O. Box 25000, Orlando 32816. During the summer of 1981, a U.S. Department of Education Physical Science Institute was held at the University of Central Florida for thirty-five kindergarten through fourth grade teachers. A prime objective of the institute was to make a positive change in the feelings that most elementary school teachers have about teaching science, by a four-week total immersion in an activity oriented science program. A modified static group comparison was employed and the data collected indicate a significant gain in positive attitude toward teaching science accompanied by a significant drop in anxiety level.

2:00 pm BREAK

2:15 pm TCH-191 How to Set Up and Use a Successful Astronomy Day. DARYL L. SCHRADER, St. Petersburg Junior College, P. O. Box 13489, St. Petersburg, FL 33733. The techniques for setting up a successful Astronomy Day are given from actual experience. Such an endeavor can be useful for generating interest in Science from the general public and students.

2:30 pm TCH-192 Does "Saxon" Algebra Teach High School Students More Algebra? BETTY P. PREECE, Melbourne High School, Melbourne, FL 32901. John Saxon has created much interest with his "repetition for mastery" method of teaching algebra. Because too many Melbourne High students were not making satisfactory progress in learning algebra from conventional texts, the author began teaching Saxon method to two classes in December, 1981. At the end of the school year in June, all Melbourne High algebra students took the same progress tests. Results inducate that Saxon students were able to learn nearly as much algebra in one semester as regular algebra students did in two semesters. During the 1982-3 school year, the author has taught one Saxon and one regular algebra class. Some preliminary results from these programs will also be presented.

2:45 pm TCH-193 Crisis in Pre-College Science Education. JAMES G. POTTER, Florida Institute of Technology, Melbourne, 32901. The U.S. is losing its margin of ascendency in Science and Technology because increasing numbers in most of the rest of the world are getting rigorous pre-college preparation in the sciences. Although high education is not provided for all, many for instance, study Physics for five years prior to college. They have multiple exposures to physical concepts and reasoning at a concrete level preparing them well for later formal abstract reasoning. Before college they learn more than do most American college sophomores. We must foster development of interest in science before college and provide more and better science instruction for those capable and interested. Ways must be found to involve many more professional scientists in pre-college education.

SATURDAY 3:00 pm Donald R. Shephard Seminar Building, Black 2
BUSINESS MEETING: Science Teaching Section
M.L. IVEY, St. Petersburg Junior College, presiding

SOCIAL SCIENCES

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

SATURDAY 9:00 am Donald R. Shephard Seminar Building, Black 2
W.D. TROPF, University of Central Florida, presiding

9:00 am SOC-194 Three Recurring Electromyographic Research Problems, R. NELESEN AND JOHN DIETER, Department of Psychology, University of Central Florida, Orlando, FL 32816. Three recurring problems in electromyographic (EMG) biofeedback research were investigated. (1) It was found that pre-knowledge that research will involve biofeedback can result in a selective bias on the part of students who are asked to volunteer as subjects; (2) EMG readings were not affected by repeated use of the word relax in verbal instructions, and (3) the forearm extensor was the only muscle group investigated to show statistically significant effect following one 20-minute training session. Both the differences and the synergistic relationship between research and application were described and endorsed.

9:15 am SOC-195 Pretraining and Muscle Relaxation While Playing Video Game. P. PHILLIPS AND R. PRATHER, Department of Psychology, University of Central Florida, Orlando, FL 32816. Nelesen and Uliano (1982) found that playing a video game significantly increased the electromyograph (EMG) reading from non-involved groups. Subjects in this study were naive, i.e., had received no pre-training in either muscle relaxation or playing of video games. This current study replicated the Nelesen and Uliano study but with the exception of pre-training trials in both muscle relaxation and video game which were administered prior to test trial.

9:30 am SOC-196 Interaction of Biofeedback and Video Game on Myopotential. R. NELESEN AND K. ULIANO, Department of Psychology, University of Central Florida, Orlando, FL 32816. The reaction of individuals to induced stress and the relationship of video games with stress as measured by electromyograph (EMG) was investigated. Subjects were assigned to three conditions: video game, active visual stimulation, neither video game nor visual stimulation. Each of these conditions was further divided to receive or not receive audio feedback correlated with Ss' EMG levels. Subjects involved in video games showed significantly higher EMG levels than Ss from either control group. Audio feedback demonstrated no significant effect.

9:45 am SOC-197 MBERT: A BASIC Program to Alleviate Experimenter Effect in Biofeedback Research. KEVIN C. ULIANO AND ROY E. CONNALLY, Univ. of Central FL, Dept. of Psychology, Orlando 32816. The recent proliferation of microcomputers has provided researchers with a new alternative for isolating and/or controlling for experimenter bias in a biofeedback laboratory situation. The MBERT program described in this study is written in Applesoft BASIC. The program can be seen as bi-modal and interactive. It takes a series of four variables (i.e. monitoring machines, muscle groups, tasks, and baseline period) which are defined by the experimenter, and executes them at appropriate times during the subject's trial. The S' is asked to perform a task which is prescribed by the experimenter. The menu of tasks includes but is not limited to commercially available programs which deal with eye-hand coordination and cognitive processes. The availability and adaptability of the MBERT program is also discussed.

10:00 am BREAK

10:15 am SOC-198 Welcome Back, Teacher. R. LA ROWE AND R. CONNALLY, Department of Psychology, University of Central Florida, Orlando, FL 32816. Within a restricted range, test frequency was compared with lecture frequency for teaching effectiveness. Criterion for effectiveness was student performance on objective tests. Two lectures and one test per week resulted in higher test performance than one lecture and two tests per week. With regard to earlier research, it was suggested that there is some, as yet undefined, point-of-no-return for test frequency as a teaching tool. Necessary research was described.

10:30 am SOC-199 Forecasting Florida Farm Labor. DJEHANE HOSNI, Economics Department, University of Central Florida, P.O. Box 25000, Orlando, Florida 32816. Data for the last four years on farm labor in the State of Florida, including regional distribution (North, Central and South) were acquired and analyzed to determine the next two years' forecast. Best smoothing factors for permanent component, seasonal and trend were identified using the single, double and triple exponential smoothing models. The model with the smallest average mean absolute error for each case was selected. Winter's seasonal forecasting model was applied to the data using best smoothing factors. The project resulted in forecasting local, intrastate, and interstate migrant labor for the 1983 season. Initial forecasting indicators are being verified. It appears that the model used can best fit this type of application where citrus farming impacts the seasonality of farm labor hiring in Florida.

10:45 am SOC-200 The Voting Rights Act and Old Hypotheses on the Old South. MARK STERN, Department of Political Science, University of Central Florida, Orlando, FL 32816. This study examines the traditional hypotheses concerning the development of Black electoral participation in the South. It is shown that the Voting Rights Act of 1965, and its subsequent amended extensions, have led to previously unanticipated sources of such participation.

SATURDAY 11:00 am Donald R. Shephard Seminar Building, Black 2
BUSINESS MEETING: Social Sciences Section
W.D. TROPF, University of Central Florida, presiding

URBAN AND REGIONAL PLANNING

FRIDAY 1:30 pm W. Lansing Gleason Auditorium
PLENARY SESSION I: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 2:30 pm Donald R. Shephard Seminar Building, Black 2
E.L. MOSURA, Water and Air Research, Inc., presiding

2:30 pm URP-201 BASIS and the Management of Tampa Bay. E.D. ESTEVEZ, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. Tampa BASIS (acronym for Bay Area Scientific Information Symposium) was a conference of scientists and resource managers held in 1982. Fifty invited review and contributed papers on the physical, chemical and biological organization of Tampa Bay were read. Sections on anthropology and cultural impacts were also included. Major conclusions of the symposium were that the bay is relatively well studied, specific new studies are needed, and that the bay is manageable as an ecological unit. Developing the need and opportunity for holistic management became the objective of a baywide study committee created in 1982 within the Tampa Bay Regional Planning Council and funded by a coastal zone management grant during 1983. Subcommittees on ecology and other topics will formulate goals for improved bay management, identify obstacles to attaining the goals and develop implementation strategies. Progress made to date by the study committee is the subject of this report.

2:45 pm URP-202 Anthropogenic Impact on a Small Coastal Lagoon System: Local Land Use Considerations. ANE D. MERRIAM, JEFFREY H. PARKER, AND CHRISTOPHER M. TEAF, Institute of Science and Public Affairs, Florida State University, Tallahassee, Florida 32306. Several indicators of stressed or seriously degraded water quality were found during sampling of physical and biological parameters in East Pass Lagoon, Destin, Florida. These included severely restricted tidal flushing, strongly elevated sedimentary microbial biomass measurements in some sections of the lagoon, and alterations in normal microbial community structure parameters, extremely low dissolved oxygen levels and low fish species diversity. Several factors in local land use patterns can be identified which contribute to the observed degradation in water quality. Recommendations were made to the local county commission regarding proposed modifications in existing drainage, stormwater runoff, potential for limited dredging of selected sections of the lagoon, and limitation of future development surrounding the lagoon. The case is similar to many other enclosed estuarine systems common to the Florida coast, hence decisions made may serve as a model for other communities experiencing similar situations.

3:00 pm URP-203 LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY. E.D. Estevez, S.A. Rice, R.R. Lewis and B.D. Fortune, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. A shoreline inventory of the lower Hillsborough River was conducted during the summer and fall of 1982 as part of National Urban Runoff Program studies in the City of Tampa, Florida. Existing shoreline conditions, including the extent and use of public shores, and stormwater outfalls were catagorized. Approximately 54% of the lower river shoreline has been hardened by bulkhead, riprap, or other structures. Public shores on the river are in varied condition but include segments worthy of immediate improvement. Vegetation trends on this urbanized river were mapped and analyzed. Five species indicative of long term salinity regimes were encountered on the banks of the lower River. No clear pattern of zonation was evident among these plants. Opportunities for increasing native shoreline vegetation, modifiying existing stormwater outfalls and public shores for the purpose of improving water quality were identified. Approximately 3,200 ft of shoreline vegetated by Australian pine or Brazilian pepper could be eligible for restoration as native estuarine shoreline. This study was supported by a grant from the City of Tampa to S.A. Rice.

3:15 pm URP-204 Cultural Resource Assessments as a Planning Tool. MARTIN F. DICKINSON AND LUCY B. WAYNE, Water and Air Research, Inc., P.O. Box 1121, Gainesville, FL 32602. Cultural resource surveys of two sites in Marion and Sumter Counties were conducted as part of an environmental impact statement. Data obtained from the surveys is being used in the planning process for the proposed Veterans Administration cemetery. Cultural resource information is correlated with environmental data to produce potential site location models. Use of such models early in the planning stages of projects has several benefits: (1) protects resources; (2) averts costly mitigation projects; (3) may enhance the project; (4) averts legal dilemmas; (5) increases knowledge of area resources. Data from this project was compared to an earlier Withlacoochee Regional Planning Council model. It demonstrated the need for field testing of regional models and the increased need for refinement of models through extensive field work.

3:30 pm BREAK

3:45 pm URP-205 Proposed Water Shortage Plan. Richard S. Owen and Linda R. Cannon. SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT (SWFWMD), 2379 Broad Street, Brooksville, 33512-9712. To deal with future water shortages in an efficient and equitable manner, the SWFWMD plan describes the criteria and procedures for declaring a water shortage, and details specific water use restrictions that can be enforced throughout any area of the District where water shortage conditions are determined to exist. Three phases of water shortage are established: moderate, severe, and extreme. Each phase has specific restrictions associated with it, which are designed to achieve progressively greater percent reductions in overall total water use. If greater reductions in water use are necessary, a water shortage emergency may be declared and additional restrictions imposed. The water shortage plan is flexible in that additional restrictions deemed appropriate and necessary may be imposed during any phase, and restrictions may vary between geographical areas, sources of water, and methods of withdrawal. The water shortage plan can be applied to all water users, including those not subject to the District's Consumptive Use Permitting Program.

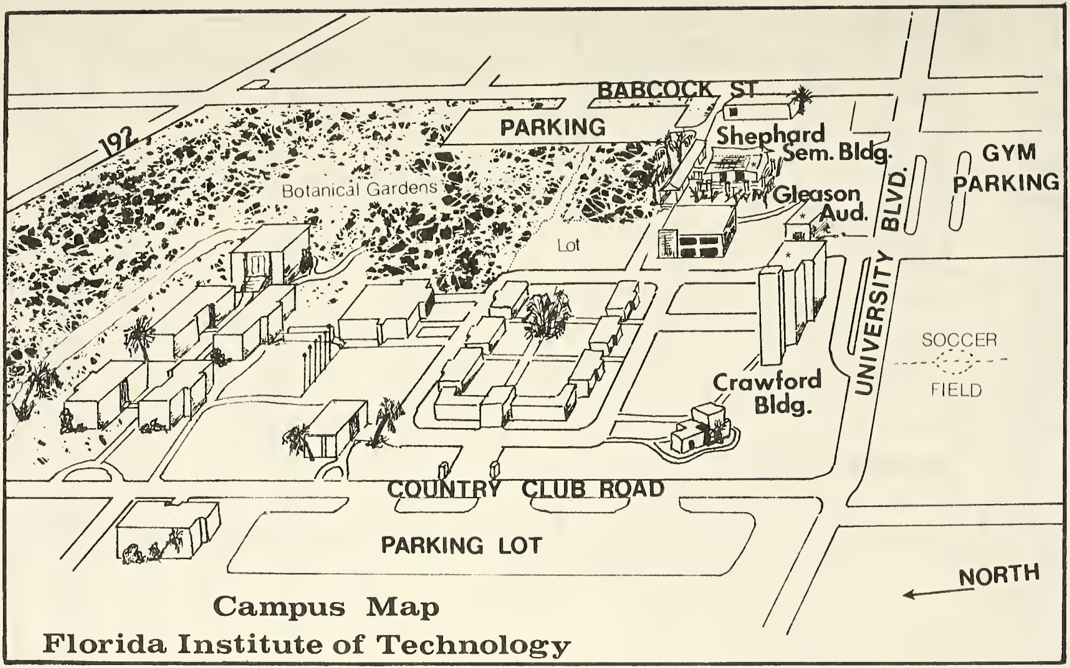
4:00 pm URP-206 Model Flood Management Ordinance. C.E. Comer, Southwest Florida Water Management District, 2379 Broad Street, Brooksville, 33512. Despite the increased emphasis being placed on effective management of flood plains and wetlands, development continues to occur in these ecological and environmentally sensitive areas. One of the factors which has been missing in the scenario of flood plain and wetlands management is a comprehensive ordinance which addresses the technical and legal issues. To meet the demands of the rapidly growing communities in Southwest Florida, a model ordinance has been developed. The ordinance, as written, offers a complete set of criteria on permit and administrative procedures, the conditions for denial and a thorough legal analysis of current law and enabling legislation. The model ordinance, coupled with the volume of technical data already developed, will assist local governments with the tools necessary to establish an effective land and water management program.

4:15 pm URP-207 Identification, Evaluation, and Preparation of Development Standards and Guidelines for the Wetlands of Seminole County. MARK T. BROWN, Center for Wetlands and Department of Urban and Regional Planning, University of Florida, Gainesville 32611. The wetland ecosystems of Seminole County, Florida, were classified. Nine biological and physical values were determined for wetlands. Data were assembled to indicate the importance of each wetland with respect to each value. A method was developed for evaluating the compatibility of possible development activities with each wetland ecosystem. Based on the evaluation scheme and impact of possible development activities, a model Wetlands Development Ordinance for Seminole County was drafted. Project supported by contract to the Board of County Commissioners of Seminole County with funds from the Florida Department of Community Affairs under the Local Government Comprehensive Planning Assistance Program.

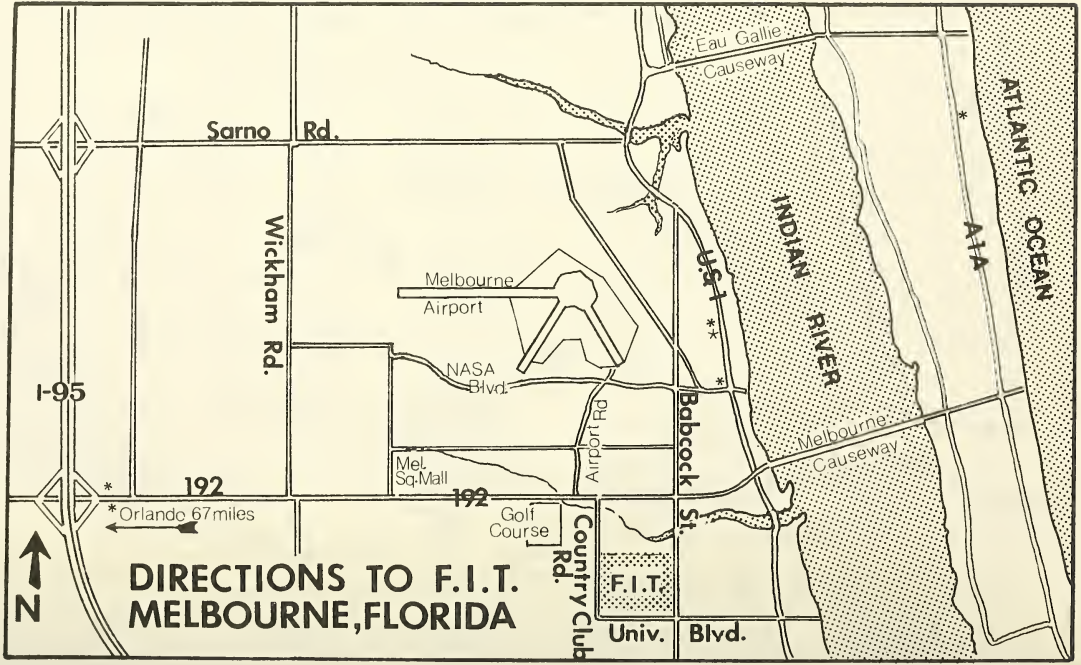
4:30 pm URP-208 Permitting procedure for wetland development ordinance in Seminole County, Florida. Earl M. Starnes and Mark Brown, University of Florida, 431 ARC, Gainesville, FL 32611. This paper describes the procedures for review and administrative analysis of developments proposed in the seven categories of wetlands in Seminole County. It describes each step in the procedure, the appeals process and finally, the means employed for issuing or rejecting permits for developments in wetlands.

FRIDAY 4:45 pm Donald R. Shephard Seminar Building, Black 2
BUSINESS MEETING: Urban and Regional Planning Section
E.L. MOSURA, Water and Air Research, Inc., presiding

FRIDAY 6:30 pm Holiday Inn Melbourne Oceanfront, Aruba Room
BANQUET and PLENARY SESSION II: The Florida Academy of Sciences
E.F. STROTHER, Florida Institute of Technology, presiding



Campus Map
Florida Institute of Technology



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PROPORTIONAL SKELETAL MASS IN TURTLES

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ABSTRACT: *The relations of carapace length and skeletal mass to body mass in several turtle species were examined. In nearly all species the log of body mass varies in proportion less than 3 times the log of carapace length. This differs from the usual condition in other reptiles where the proportion is 3 or more. The exponent of the power function relating skeletal mass and body mass averaged 1.11 and was similar to published data from other vertebrates and invertebrates. Some intraspecific (populational and sexual) variation in the relationships of both carapace length and skeletal mass to body mass was evident. Relative percent of body mass in skeletal mass was significantly higher in most turtles examined (2.4–40.4%) than in other animal groups studied (4–18%), except freshwater mollusks (12–34%).*

BECAUSE turtles (order Testudines) have perhaps the most modified skeleton of any vertebrate and because they exploit habitats ranging from completely terrestrial to fully aquatic, it is surprising that scaling of skeletal tissues in the group has been so neglected. Among the vertebrates, turtles would seem to be the best subjects for analysis of the upper limits of relative supporting tissue mass in motile organisms. Anderson et al. (1979) previously found no motile organisms (including land mammals, whales, birds, spiders, and rattlesnakes) in which support tissue exceeded 20% of total body mass. However, data from Hall (1924) and Benedict (1932) suggest that turtles may often have skeletal mass/body mass proportions far in excess of 20%.

Hall (1924) determined that the dry shell alone (without vertebrae or appendicular skeleton) constituted 16.7 to 27.0% of total body mass in 14 adult painted turtles *(Chrysemys picta marginata)*. Similarly, Benedict (1932) found that the dry "shell" and the "shell" with other bones and skin in an Iberian tortoise *(Testudo graeca)* represented 36.2 and 39.8% of body mass, respectively. He also recorded a mature female tortoise (*Geochelone* sp.) whose body shell and limb bones accounted for 31.9% of live body mass, and an unidentified turtle whose shell alone represented 27.3% of its average total body weight. In all but 1 of these cases, the inclusion of all skeletal elements would have pushed the percentages upward.

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The paucity of skeletal mass data for turtles, the uniqueness of their skeletal adaptations among the vertebrates, and the importance of the data to physiologists, ecologists, and paleontologists alike prompted this investigation of skeletal tissue scaling in the group.

METHODS—Carapace (straight-line) length-body mass data were obtained from the literature (Table 1), colleagues, or from live, healthy turtles with free access to food and water. No attempt was made to standardize the time of day, season, or amount of food or water in the turtle's gut when weighed. Because of great individual, seasonal, and even daily variability, body masses for lower vertebrates have seldom been reported in the scientific literature. Among other things, this deficiency in data is responsible for the lack of biomass estimates for turtle populations, and it has hampered or made impossible numerous physiological comparisons (see Pough, 1980; Hopson, 1980.)

Turtle carcasses were macerated in water to remove all flesh and cartilage. Bony skeletons (including axial and appendicular components) were air dried for at least 1 wk prior to weighing to the nearest 0.1 gm. In some cases total body mass was estimated for weighed skeletons by using the carapace length-body length regression; those estimated data are so noted in the text. Skeletal mass data were preferentially obtained from adult turtles. Juvenile weights have not been included due to the observed ontogenetic increase in relative skeletal mass (see later). Sex of skeletons was not always known.

Data were fitted to the general allometric equation (power function) $y = ax^b$, in the form log $y = \log a + b (\log x)$, by the method of least squares regression analysis (Anderson et al., 1979; Reynolds and Karlotski, 1977). Correlation coefficients were also calculated as a measure of the reliability of the regression equation. All measurements are in cm or gm.

Body mass versus body size regressions of turtle body mass on carapace length by species appear in Table 1. As would be predicted, the highly significant power function exponents (slope in the log-log regression) are near 3.0 ($\overline{X} = 2.754 \pm 0.313$; range 1.78–3.21, N = 39 samples and 25 species). However, exponents for the 4 available sea turtle samples (family Chelonidae) are among the 6 lowest statistically significant values (the other 2 have small sample sizes) and average only 2.144 (range, 1.784 to 2.583). The data suggest that turtles in general scale body mass to carapace length at slightly less than a power of 3, and that sea turtles scale those variables at a power just over 2.

Comparative data available from other reptiles groups demonstrate considerable variation around the expected cubic relationship between length and weight. Body (snout-vent) length-weight regression equations for 13 species of South Carolina snakes had exponents of 2.55 to 3.30 ($\overline{X} = 2.96$) (Kaufman and Gibbons, 1975); and male and female black rat snakes *(Elaphe guttata)* from Maryland had exponents of 3.11 and 3.32, respectively (Stickel et al, 1980). Exponents for the same regression for 3 crocodilian species ranged from 3.23 to 3.32 (X = 3.27) (Vanzolini and Gomes, 1979). Similarly, the body length–weight regression exponent for the iguanas *Cyclura carinata* (Iverson, 1979), *Cylcura cychlura* (Iverson, unpublished), and *Ctenosaura similis* and *Iguana iguana* (Van Devender, 1982) are 3.03, 2.97, 3.07, and 3.15, respectively. Calculations by Pough (1980) for lizards (636 specimens of 47 species of 12 families), snakes (500 + specimens of 13 species of 2 families; data from Kaufman and Gibbons, 1975), and turtles (508 specimens of 31 species of 9 families) revealed exponents of 2.98, 3,02, and 2.69, respectively.

TABLE 1. Relationship of body mass (Y) and carapace length (CL;X) in various turtle species, based on the equation $Y = aX^b$. Samples are listed in decreasing order of exponent (b). All units are cm or gm. Regressions calculated from data in other sources are indicated. Statistical significance of correlation coefficients is indicated (*, p <5%; **, p <1%).

Species	N	CL range	b	a	r
Pseudemys scripta[1] (Georgia)	8	14.2-19.8	3.213	.0958	.991**
Graptemys geographica (Indiana)	20	5.2-21.5	3.156	.0728	.885**
Kinosternon herrerai	12	9.0-15.5	3.095	.1136	.991**
Kinosternon scorpioides abaxillare	6	12.4-14.4	3.066	.1153	.943**
Chelydra serpentina[2] (Michigan)	151	ca 19.7-37.5	3.064	.1837	----**
Kinosternon integrum	20	2.8-16.4	2.996	.1441	.998**
Kinosternon flavescens (Nebraska)	253	2.1-13.0	2.988	.2293	.996**
Terrapene ornata	28	4.8-11.8	2.954	.2756	.985**
Trionyx spiniferus[3]	37	5.2-43.2	2.951	.1012	.998**
Chelydra serpentina[4] (Michigan)	151	ca 19.7-37.5	2.93	.00034	----**
Kinosternon oaxacae	11	9.3-17.5	2.927	.1519	.990**
Kinosternon leucostomum (Mexico)	14	10.7-16.6	2.924	.1771	.986**
Kinosternon scorpioides cruentatum (Mexico)	7	8.7-14.3	2.902	.2212	.990**
Lissemys punctata[5]	6	20.0-22.0	2.897	.1813	.795
Kinosternon flavescens (Arizona)	38	2.5-16.7	2.889	.2144	.999**
Kinosternon hirtipes (Chihuahua)	149	4.6-14.2	2.887	.1931	.993**
Kinosternon baurii	6	7.3-9.6	2.867	.2490	.977**
Gopherus polyphemus[6]	66	5.6-24.6	2.815	.2652	.994**
Chrysemys picta (Nebraska)	44	7.5-17.5	2.812	.2149	.989**
Chelydra serpentina[7] (New York and Wisconsin)	240	20.0-33.5	2.80	.00046	----**
Graptemys geographica[8] (Michigan)	76	ca 3-ca 21	2.796	.1939	.996**
Chrysemys rubriventris[9]	18	4.2-32.3	2.790	.2692	.999**
Podocnemis unifilis[10]	32	24.5-43.5	2.783	.2070	.940**
Kinosternon alamosae	23	7.3-12.4	2.780	.2136	.978**
Sternotherus odoratus[8] (Michigan)	81	ca 2.0-ca 11.5	2.766	.2473	.998**
Sternotherus odoratus[11] (Indiana)	171	3.7-13.7	2.766	.1815	.968**
Emydoidea blandingi[12] (Indiana)	7	13.2-21.0	2.758	.2743	.974**
Staurotypus salvinii	4	12.3-16.4	2.738	.3276	.995**
Kinosternon hirtipes (non-Chihuahua)	18	9.0-15.1	2.732	.2942	.980**
Kinosternon baurii[13] (Florida Keys)	157	ca 2.0-ca 11.9	2.723	.2642	.999**
Sternotherus odoratus (Indiana)	17	8.1-9.9	2.692	.3181	.927**
31 species of 9 families[14]	508	2.8-179.0	2.690	.390	?
Chrysemys picta (Indiana)	107	3.0-14.7	2.681	.2823	.924**

TABLE 1. Continued.

Species	N	CL range	b	a	r
Chrysemys picta[8] (Ohio)	85	ca 2.5-ca 15.0	2.646	.3169	.998**
Chelonia mydas[15]	22	100.3-121.9	2.583	.8649	.754**
Geochelone elegans[5]	8	13.8-28.0	2.548	.6360	.970**
Chelonia mydas[16]	15	97.8-132.1	2.247	4.3793	.842**
Eretmochelys imbricata[5,15,17]	28	40.0-88.9	1.962	10.2149	.940**
Melanochelys trijuga[5]	8	19.8-23.5	1.846	4.3439	.858**
Lepidochelys olivacea[15]	14	64.1-71.8	1.784	18.9603	.532*
Clemmys guttata[11]	10	8.7-9.7	1.056	10.892	.355

[1] Raw data courtesy Betsey Reitz.
[2] Data from Lagler and Applegate (1943).
[3] Data recalculated from Dunson (1967).
[4] Data from Lagler and Applegate (1943), as recalculated by Mosimann in Dunson (1967); units apparently incorrect.
[5] Deraniyagala (1939).
[6] Data from Goin and Goff (1943), as calculated by Iverson (1980).
[7] Yntema (1970); units apparently incorrect.
[8] Mosimann (1958).
[9] Graham (1971).
[10] Smith (1979).
[11] Evermann and Clark (1916) (weighed in ounces; accuracy questionable).
[12] Raw data from Wade and Gifford (1965).
[13] Dunson (1981).
[14] Pough (1980).
[15] Pritchard (1969).
[16] Carr and Hirth (1962).
[17] Hirth and Carr (1970; all gravid females).

These data confirm the distinctiveness of turtle body structure at least among reptiles. Power function exponents for body mass-body length regressions are significantly lower than those available for the other reptile groups. However, comparing turtles with other vertebrates is made difficult because body length in the other groups includes the head, whereas for turtles, it does not. Nevertheless, an exponent less than 3 implies that: 1.) body length (relative to mass) increases more with size than in groups with cubic exponents, or 2.) body mass (relative to body length) decreases more with size than in the other groups, or 3.) both.

At least the first of these alternatives may indeed apply to turtles. If, ontogenetically, carapace length makes up a greater proportion of the turtle's rostrum-to-vent length (i.e., actual body length), then carapace length-body mass exponents would be expected to be less than rostrum-to-vent length-body mass exponents. For turtles, if the latter were a cubic relationship (as for other groups), exponents less than 3 would not be surprising at all for the former. Unfortunately, rostrum-to-vent length data are not available for turtles; but, my subjective impression is that carapace length does in fact increase with age relative to "actual" body length (juvenile turtles appear to have bigger heads than older turtles).

The second alternative might also apply if there were an ontogenetic trimming of mass in turtles, which are already among the heaviest of vertebrates (compare, for example, a lizard and turtle of the same body length). Such a trend would seem to be adaptive for turtles, and might be accomplished by reducing relative carapace width or height, or body density, with age. Unfortunately the critical data are not available to permit an evaluation of these variables.

Whatever the explanation(s), the question remains why sea turtles should have smaller regression exponents than most other turtles. I can only suggest that it might be related to the relatively smaller carapace of sea turtles, that does not permit the withdrawal of the head inside the shells, as in most other turtles.

Skeletal mass allometry-The relationship between skeletal mass and body mass for 21 North American turtle species is also quite variable, both among and within species (Table 2; Fig. 1). Statistically significant power function exponents average 1.106 ($N = 19$) but range from 0.786 to 1.368. A regression of all unestimated data for all species coded in Table 2 (plotted in Fig. 1) is highly significant ($y = .3460X^{.9306}$; $N = 61$; $r = .891$; $p < 0.01$) and also has an exponent near one. However, if the structurally atypical softshell turtles *(Trionyx)* and the snapping turtles *(Chelydra)* are not included, the regression is much more significant ($y = .2507X^{.9997}$; $N = 56$; $r = .975$) and the exponent is insignificantly different from one. That regression suggests that skeletal mass averages 25% of body mass in typical turtles, regardless of body weight.

Skeletal mass-body mass regressions for single subspecies (or populations) are typically highly significant, whereas the regressions of data including more than 1 subspecies tend to be less significant (Table 2). This suggestion of the existence of intraspecific variation in the skeletal mass-body mass regression is supported by the data from *Pseudemys scripta* and *Kinosternon scorpioides* (Table 2, Fig. 1). Although sample sizes are not large, both the actual percent of skeletal mass/body mass and the rate of allometric change in that relationship in different subspecies (geographic variants) of these species are very different. An analysis of geographic variation in skeletal scaling in a common, polymorphic species like *Pseudemys scripta* would be very helpful in understanding the reasons for the observed variation. I predict that significant geographic variation in this relationship will characterize many turtle species.

The only skeletal mass-body mass data available for any other reptile group is that of Prange and Christman (1976) for the diamond-back rattlesnake *(Crotalus adamanteus)*. They found the 2 variables to be significantly related by the equation $y = .020X^{1.174}$ (y = skeletal mass), which has an exponent very similar to that for the turtle data. Likewise, Anderson et al. (1979) have pointed out the similarity of power function exponent values for supportive tissue mass-body mass comparisons in organisms as diverse as spiders, mollusks, rattlesnakes, birds (and eggs!), land mammals, and whales. The average value they calculated (1.12) is nearly identical to that observed for turtles (1.106). However, Reynolds (1977), in a comparison of skeletal mass allometry in aquatic vs. terrestrial vertebrates, suggested that because of the buoyant effects of water, skeletal mass in aquatic forms

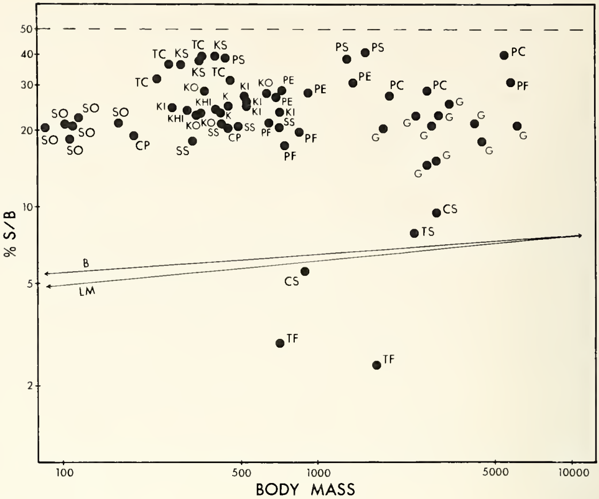

FIG. 1. Relationship between body mass and skeletal mass (S) as percentage of body mass (B) in turtles, based on nonestimated data. Species abbreviations are in Table 2. Reference regressions from Anderson et al. (1979) for birds (B) and land mammals (LM) are also plotted.

should vary in direct proportion to body weight (exponent ≅ 1.0), whereas skeletal mass proportions should increase with increasing size (exponent > 1) in terrestrial organisms that must support their weight on land. His hypothesis seemed to be supported by the bird, mammal (including whale), snake, bony fish, and lamprey data available to him, but recent data (Prange et al., 1979; Anderson et al., 1979) make this hypothesis more tenuous. In addition, no aquatic-terrestrial dichotomy in skeletal scaling exists for turtles (Table 2); the fully terrestrial *Gopherus polyphemus* scales skeletal to body mass with an exponent close to 1, and most aquatic turtles scale with exponents much greater than 1. It appears that scaling differences in aquatic versus terrestrial organisms may not be as great as Reynolds (1977) hypothesized.

Skeletal mass proportions-Anderson et al. (1979) found that maximum support tissue mass approaches only 18% of body mass in whales, 14% in land mammals, 9% for birds, 8% in rattlesnakes, and 13% in spiders. They suggested that the upper limit for relative support tissue mass in motile animals is 20%. Their data from 3 species of freshwater mollusks, however, revealed shell mass/body mass percentages of 12 to 34. Clearly the turtle data demonstrate that even among the vertebrates, skeletal tissue can significantly exceed 20% of body mass (Fig. 1).

Percentages near 40% have been recorded for at least 4 turtle species: 1 terrestrial *(Terrapene carolina)*, 1 semi-terrestrial *(Kinosternon scorpioides)*

TABLE 2. Relationship of skeletal tissue mass (Y) to total body mass (X) based on the equation $Y = ax^b$. All units are gm. Statistical significance of correlation coefficients is indicated (*, p <5%; **, p <1%).

Species	Code	Habit[1]	N	% Y/X	X Range	b	a	r	Source
Chrysemys picta	CP	A	2	19.8 9.1-20.4	192-445	–	–	–	Indiana
Graptemys geographica	—	A	2	20.1 15.9-24.3	320-940	–	–	–	Indiana
Pseudemys concinna	PC	A	3	32.2 27.6-40.2	1890-5500	1.368	.0166	.998**	Florida[3]
Pseudemys floridana	PF	A	4	22.4 17.6-30.7	650-5890	1.213	.0481	.997**	Florida[3]
Pseudemys scripta elegans	PC	A	4	28.6 26.7-31.0	696-1384	1.176	.0860	.997**	Louisiana-Mississippi[3]
Pseudemys scripta scripta	—	A	8	31.3 28.3-34.4	473-1481	1.092	.1688	.984**	Georgia[3]
Pseudemys scripta scripta	PS	A	3	39.1 38.4-40.4	440-1560	1.020	.3418	.999**	Florida[3]
Trionyx ferox	TF	A	2	2.7 2.4-2.9	715-1710	–	–	–	Florida[3]
Trionyx spiniferus	TS	A	1	8.0	2424	–	–	–	Indiana
Chelydra serpentina	CS	BW	2	7.6 5.7-9.6	900-2977	–	–	–	Florida-Indiana[3]
Chelydra serpentina	—	BW	4	10.26 8.9-12.4	850-5682	1.124	.0377	.996**	Indiana
Deirochelys reticularia	—	BW	2	23.4 21.7-25.0	552-1119	–	–	–	Florida-Georgia[3]
Kinosternon flavescens	—	BW	1	21.7	208	–	–	–	Nebraska
Kinosternon herrerai	K	BW	2	24.5 23.7-25.2	415-445	–	–	–	Mexico
Kinosternon hirtipes	KHI	BW	2	24.2 24.1-24.3	310-395	–	–	–	Mexico
Kinosternon hirtipes[2,4]	KHI	BW	45	22.3 13.1-31.4	148-813	1.116	.0889	.945**	Mexico
Kinosternon integrum	KI	BW	5	25.4 23.8-27.5	270-710	.999	.2546	.986**	Mexico

TABLE 2. Continued

Species	Code	Habit[1]	N	% Y/X	X Range	b	a	r	Source
Kinosternon integrum[2]	KI	BW	11	24.5 21.9-27.5	270-710	1.074	.1554	.971**	Mexico
Kinosternon oaxacae	KO	BW	4	25.9 23.0-28.7	335-630	1.253	.0564	.971*	Mexico
Kinosternon subrubrum subrubrum	—	BW	4	27.1 23.6-29.0	94-170	1.362	.0453	.999**	Georgia[3]
Staurotypus salvinii	SS	BW	4	20.2 18.2-21.2	325-709	1.130	.0910	.990**	Mexico
Sternotherus odoratus	SO	BW	6	20.7 18.4-22.3	86-165	1.090	.1352	.967**	Indiana
Sternotherus odoratus[2]	SO	BW	12	20.2 18.0-22.3	81-165	1.055	.1556	.953**	Indiana
Kinosternon scorpioides cruentatum	KS	SA	3	37.8 36.5-39.1	295-395	1.229	.0995	.999**	Mexico
Kinosternon scorpioides cruentatum[2]	KS	SA	5	37.2 36.2-39.1	174-395	1.071	.2496	.998**	Mexico-Belize
Kinosternon scorpioides albogulare[2]	KS	SA	10	30.2 25.7-35.7	316-893	.810	.9899	.935**	Costa Rica
Kinosternon scorpioides[2,4]	KS	SA	15	32.6 25.7-39.1	174-893	.786	1.1824	.962**	Mexico, Belize, and Costa Rica
Gopherus polyphemus	G	T	10	20.3 14.7-25.6	1810-6123	1.049	.1345	.896**	Florida[3]
Terrapene carolina	TC	T	4	35.0 31.5-39.3	235-460	.943	.4828	.940	Florida-Mississippi[3]
Terrapene ornata	—	T	2	26.4 25.7-27.0	340-422	–	–	–	Nebraska

[1] BW = Bottom Walker (aquatic); A = swimmer (aquatic); SA = semiaquatic-semiterrestrial; T = terrestrial.
[2] Includes body mass data estimated from appropriate regression in Table 1.
[3] Includes data supplied by Betsey Reitz.
[4] Includes more than 1 subspecies.

and 2 aquatic (*Pseudemys concinna* and *P. scripta*); and they average 24.7% (27.2%, excluding *Chelydra* and *Trionyx* spp.) for 26 extant populations (Table 2). In addition, based on the body mass-carapace length regression for *Podocnemis* in Table 1 and the body mass-skeletal mass regression for turtles excluding *Trionyx* and *Chelydra* (see above), the largest turtle ever known to exist (the extinct *Stupendemys geographica*, a relative of *Podocnemis;* Wood, 1976) weighed approximately 774 kg, 24.9% of which was skeleton.

There seems to be little relationship between skeletal mass percentage and turtle habit, although "bottom-walking aquatic" species may generally have lighter skeletons. Average percentages for 7 "swimming aquatic" turtle species and subspecies range from 2.7 to 39.1% (mean, 23.0; 28.9%, excluding *Trionyx* spp.); those for 9 bottom-walking species, from 7.6 to 27.1% (mean, 21.7%; 23.5%, excluding *Chelydra serpentina*); those for 2 semi-aquatic subspecies from 30.2 to 37.2% (mean, 33.7%) and those for 2 terrestrial species, from 20.3 to 35.0% (mean, 27.7%).

One trend, however, is evident. Aquatic and terrestrial turtles each have representative populations with atypically high and low skeletal mass proportions. That is, skeletal reduction and proliferation have apparently occurred in both aquatic and terrestrial turtles. Clearly the greatest reduction has been among certain of the aquatic turtles (e.g., *Chelydra* and *Trionyx*), although data from the African pancake tortoise (*Malacochersus*), when available, may reveal an equivalent reduction in that truly terrestrial form. Equal levels of proliferation are likewise evident in aquatic and terrestrial species. Unfortunately, much additional ecological as well as relative skeletal mass data must be collected before the adaptive significance of this variation can be fully understood. However, one factor possibly responsible for this great variation within a habit type may be predation.

The proliferation of the skeleton of turtles beyond typical proportions, whether in aquatic or terrestrial forms, may have been a response to increased predation pressure. For example, "swimming-aquatic" turtles in Florida generally have very heavy, strongly buttressed, high-domed shells. In fact, the Floridian subspecies of both *Pseudemys scripta* and *P. concinna* have much higher domed shells than their respective continental subspecies, and therefore apparently also have significantly higher skeletal mass proportions (Table 2). These particular examples of skeletal proliferation may have been responses to increased predation intensity in peninsular Florida, possibly due to the present and historical (Neill, 1971; especially p. 122) abundance of predaceous crocodilians.

Skeletal proliferation in certain terrestrial and semi-terrestrial turtle populations (e.g., *Terrapene carolina* and *Kinosternon scorpioides*) may similarly be an evolutionary response which reduces the extent of soft part exposure (the "box turtle" effect) and increases the depth and buttressing of the shell (requiring greater carnivore jaw gape and strength to crack).

Analogously, skeletal reduction may have been possible in forms with specialized adaptations for predator avoidance: *Chelydra* with its sedentary, bottom-dwelling behavior, aggressive disposition, large body size, and cryptic appearance; *Trionyx* with its anatomical streamlining (see Dalrymple, 1977); and *Gopherus polyphemus* with its burrowing behavior and thickened integument.

Studies relating predation intensity, habits, and relative skeletal mass in turtles are clearly critical as a test of this preliminary predation hypothesis, and I would predict a positive correlation between predation intensity and relative skeletal mass for species in a given habitat or for populations within a given species.

It is also reasonable to predict that other species whose supportive tissue appears to function in protection from predation (for example, pangolins and armadillos, certain anguid lizards, crocodilians, horseshoe crabs, etc.) should have relatively high supportive or skeletal mass-body mass proportions. Future research should be directed to skeletal scaling in those organisms, as well as to studies of intraspecific (population, ontogenetic, and sexual) variation in scaling of total supportive tissue and its components in any species.

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DEVELOPMENT AND USE OF MARKING TECHNIQUES TO STUDY MANATEES IN FLORIDA

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Abstract: *From October 1975 to March 1978, a study was conducted to develop and field test techniques to mark and track manatees in Florida. Assorted "visual tags", such as freezebrands and spaghetti tags as well as sutures and peduncle straps to hold transmitters, were tested on captives and free-ranging animals. Mark-resighting results were generally unsuccessful because visibility of the marks was generally poor, but one freezebrand was sighted 45 mo after application. Sutured radio tags remained attached for up to 28 da and furnished dive activity data. One manatee was sighted in Brevard County during 3 summers and 1 winter between 1977-1980.*

Effective marking and tracking techniques are a major need to study the West Indian manatee (*Trichechus manatus*). Free-ranging manatees are difficult to study; they often occur in turbid water and can remain submerged for long periods (Husar, 1977). Moreover, the nostrils and frontal area of the head are usually the only part of the manatee to break the water's surface during respiration (see illustration in Hartman, 1979, p. 74). In Florida, manatees are reasonably accessible for study in winter because they gather at artesian springs or heated effluents from industrial or electric-generating plants to seek refuge from cold temperatures (Hartman, 1974; Irvine and Campbell, 1978). Only a few of the sites where manatees gather have clear water. Behavioral studies have been conducted at Crystal River, Citrus County, Florida (Powell, 1981; Hartman, 1979), at Blue Spring State Park, Volusia County, Florida (Powell and Waldron, 1981, and in Miami, Dade County, Florida (Moore, 1956; Reynolds, 1977; 1981a; 1981b), but seasonal movements and activities are largely unknown. Because the manatee is an endangered species, more data about movements and habitat use are needed to assist conservation and management efforts.

Marking and tracking techniques that are useful for studying free-ranging small cetaceans (Evans et al., 1972; Leatherwood and Evans, 1979) are less easily applied to sirenians, which lack an obvious attachment site such as a dorsal fin. Attempts to mark manatees with paint (Bertram and Bertram, 1964), and to attach flipper-bands and harnesses (Hartman, 1979) have been unsuccessful. Boat propeller scars and other disfigurements, which have been used to identify manatees at a few clear-water winter aggregation sites (Moore, 1956; Powell, 1981; Powell and Waldron, 1981; Hartman, 1979), are of little use when manatees disperse into turbid areas in the spring.

In this report we describe our efforts to develop and evaluate techniques to mark and track manatees. Information on movements and activities from these preliminary studies is presented.

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METHODS—We conducted tests on captive manatees at Marineland of Florida, St. Augustine, and on free-ranging animals in the Banana and Indian Rivers (Brevard County, Florida), the Withlacoochee River (Levy County, Florida), and at Blue Spring Run and in the St. Johns River (Volusia County, Florida). These sites were selected for marking activities because ongoing manatee studies by the U.S. Fish and Wildlife Service (FWS) in these areas increased the chances of resightings by experienced observers. Individual manatees are referred to by field numbers (see Table 1).

A total of 12 manatees was captured between 9 October 1975 and 20 October 1977 at the northern end of the Banana River in a dredged inlet (the "Crawler Storage Area Boat Ramp") at Kennedy Space Center (KSC), Brevard County, Florida (Table 1). The manatees were trapped in the inlet with a 3.0-m deep, 10-cm stretch-mesh net. Animals trapped together were isolated by partitioning the net. The manatees were stranded by drawing the net lead-line (bottom) up on the beach first and then pulling in the cork line (top) so that they were enclosed by an envelope of net. Eight of the newly-captured manatees were marked and immediately released at the capture site, but the other 4 were trucked to Marineland. Each manatee was restrained on a foam-padded platform by adjustable straps, and covered with damp sheets during the 2-hr trip.

At Marineland the manatees were held in a 13.4-m long x 6.7-m wide x 2.4-m deep holding tank (1.8×10^5 l capacity). The daily food ration included 28 to 42 kg of "head lettuce" (*Lactuca* sp.) and 6 Sea Tab vitamins (Appendix 1). The tank was usually drained and the manatees stranded for routine marking tests or examinations, but the animals were restrained with straps on the transport platforms during procedures where struggling was anticipated (e.g., suture application). Marking and attachment tests included use of freezebrands, aerosol paint, Paintstiks, spaghetti tags, sutures, and strap attachments (Appendix 1). Aerosol paint and Paintstiks also were applied underwater.

FREEZEBRAND—Five and 20-cm high freezebrands were applied to captives for 5-15 s using liquid nitrogen as a coolant. The brands became visible 7 to 14 da after branding. Twenty-cm brands applied for 15 s on the back in the scapula region and anterior to the peduncle caused tissued destruction characterized by 5-mm deep epidermal sloughing. Five-cm brands applied dorsolaterally at about midbody for 5, 7, or 9 s caused epidermal destruction at some "corners" of numerals where applied pressure may have been too heavy. All freezebrands were highly visible when the animals were released from captivity, up to 51 wk after application.

All 8 manatees that were captured, marked, and immediately released were freezebranded for 10-15 s with 20-cm numerals. Four free-ranging manatees were recognized by freezebrands a total of 17 times up to 45 mo (BR-10) after the brands were applied (Table 1). Except from a high-viewing angle at relatively close range (≤ 20 m), the brands were difficult to observe on free-ranging animals. When the freezebrand on BR-10 was last sighted on 11 May 1981, it was faded but distinct from a distance of about 15 m. No freezebrands were sighted from the air during bimonthly manatee census flights at an altitude of about 150 m over the Banana River from April 1977 through February 1980.

Maximum freezebrand longevity on manatees is unknown. Brands applied to manatees for 5-25 s at Miami Seaquarium in February 1975 (J. White, pers. comm.) and a brand applied for 17 s to a manatee at Sea World of Orlando in February 1977 (E. Asper, pers. comm.) were still readable in January 1981. The visibility of brands on these animals varies, however, ac-

Table 1. Results of attempts to mark and track manatees in Florida.

Field No.	Freeze-brand No.*	Spaghetti Tag No.	Marking Location	Marking Date	Length (cm)	Sex	Transmitter Type	Duration of Tracking Activities	Comments
BR-1	0	-	Kennedy Space Center (KSC), Brevard Co.	Captured: 9 Oct. 1975 Released: 13 Oct. 1975	248	M	Sonic (34 kHz)	3 days	Elastic peduncle strap; confined in capture-inlet until released; tracked in area until found dead of undetermined causes on 17 October 1975.
BR-2	2	-	KSC	Captured: 5 Mar. 1976 Released: 26 Aug. 1977	278	F	—	—	Captive at Marineland of Florida until released. Not resighted.
BR-3	-	-	KSC	5 Mar. 1976	181	F	—	—	Died in captivity of lymphatic infection on 27 Jan. 1977.
BR-4	5	0-6	KSC	27 Apr. 1977	269	F	Sonic (34 kHz)	—	Elastic peduncle strap slipped off immediately as animal moved rapidly away; recognized by freeze-brand at capture site on 13 July, 1977.
BR-5	8	-	KSC	27 Apr. 1977	175	F	—	—	Calf of BR-4.
BR-6	4	0-7	KSC	27 Apr. 1977	230	M	—	—	Recognized by freeze brand at capture site on 16 and 28 May 1977.
BR-7	3	0-8	KSC	28 Apr. 1977	282	M	Sonic (32 kHz)	—	Elastic peduncle strap ripped immediately as animal moved rapidly away; recognized by freeze-brand on 3 Oct. 1977, 15 km from capture site.
BR-8	0	0-10	KSC	28 Apr. 1977	282	M	Sonic (32 kHz)	5 h	Elastic peduncle strap; animal moved away slowly after release.
BR-9	7	0-9	KSC	28 Apr. 1977	251	M	—	—	
CIT 1	-	0-30	Withlacoochee River, Levy Co.	30 Jul. 1977	Lg.	?	Sonic (70 kHz)	55 min.	Transmitter attached to spaghetti tag; signal briefly relocated at tagging site on 31 July.

TABLE 1. Continued.

Field No.	Freeze-brand No.*	Spaghetti Tag No.	Marking Location	Marking Date	Length (cm)	Sex	Transmitter Type	Duration of Tracking Activities	Comments
BR-10	10	-	KSC	Captured: 26 Aug. 1977 Released: 16 Aug. 1978	319	M	Radio (164 MHz)	30 days	Captive at Marineland of Florida until released; transmitter sutured to plate on back, posterior to skull; transmitter observed to be lost on 19 Sep. 1978; last recognized by freezebrand on 11 May 1981; sighted up to 34 km from release site (see text).
BR-12	12**	-	KSC	Captured: 19 Oct. 1977 Released: 16 Aug. 1978	300	M	Radio (164 MHz)	19 days	Floating transmitter attached with tether to plate sutured posterior to skull; animal moved up to 8 km south of release point; last relocated on 4 Sep. 1978 (see text).
BR-11	13	Y-81	KSC	20 Oct. 1977	284	F	Sonic (34 kHz)	—	Elastic peduncle strap also held with two nylon sutures; strap lost immediately as animal moved rapidly away.
							Sonic (74 kHz)	20 min	BR-11 also marked with transmitter on spaghetti tag; signal lost despite attempts to track in 2 boats.
BR-13	-	0-74	Cape Canaveral Power Plant (FPL) Brevard Co.	7 Jan. 1978	Lg	?	Sonic (75 kHz)	13 min (16 h, monitoring time)	Transmitter on spaghetti tag; marked in effluent area.
BR-14	-	Y-4	FPL	18 Jan. 1978	Lg	?	Sonic (60 kHz)	4 days (during 11 day period; 52 h monitoring time)	Transmitter on spaghetti tag; relocation on 26, 27, 28, 29 Jan. in effluent area; tag came out or transmitter fell off near discharge outlet on 2 Feb. (see text).
BS-13***	-	Y-8	Blue Spring State Park (BSP), Volusia Co.	23 Jan. 1978	Lg	M	Sonic (50 kHz)	3 days (49 h monitoring time)	Transmitter on spaghetti tag malfunctioned; tag retrieved by diver on 26 Jan. 1978 (pulled out easily).

Table 1. Continued.

Field No.	Freeze-brand No.*	Spaghetti Tag No.	Marking Location	Marking Date	Length (cm)	Sex	Transmitter Type	Duration of Tracking Activities	Comments
BS-6***	-	Y-7	BSP	10 Feb. 1978	Lg	M	Sonic (60 kHz)	11 days (210 h monitoring time)	Transmitter on spaghetti tag found hanging in reeds in 0.8 m deep water about 6 km south of BSP on 21 Feb. 1978.
BS-X	-	Y-80	BSP	30 Mar. 1978	Lg	?	Radio (164 MHz)	8.5 h	Transmitter on spaghetti tag; animal last located 10.2 km north; transmitter and streamer recovered on 3 April (had separated from dart) in 2 m deep water.

M = male; F = female
F = female
*20 cm high brands except as noted
**5 cm-high
***1978 numbering system

Lg = large (> ≈ 2.5 m)
? = unknown
- = none
0 = orange
Y = yellow

cording to whether the manatees are shedding and possibly due to the effects of season, water temperature, and salinity.

AEROSOL PAINT—Aerosol paint, which has been used on dolphins (Watkins and Schevill, 1977), was tested on 2 manatees at Marineland. One second application of paint adhered for 7-10 da when the applicator was rubbed against the skin of the manatees, but only adhered for a few minutes when applied at a distance of 1-2 cm. Underwater application caused bubbles that startled the manatees, and paint released into the water formed a sticky slick on the surface. The use of aerosol paint was discontinued after initial tests.

PAINTSTIKS—Paintstiks are oil-based crayon-like markers usually used to temporarily identify cattle and trees. Marks applied to 3 stranded manatees at Marineland were readable after 5 wk, and traces were still visible after 6 wk. The marks smeared readily if touched during the first few hours after application, but "skinned" over and were less easily smeared thereafter. The marks caused no noticeable skin reaction, and the animals did not react to the marking process.

When tested in the Banana River, 45-cm high Paintstik marks (numerals) were observed on BR-10 from an airplane at an altitude of 150 m 45 h after application, and from a boat 7 da after application. Paintstik marks applied to free-ranging manatees by FWS divers at Crystal River, Florida, became smeared and unrecognizable within 3-5 da because the animals rubbed the marks off on other manatees or on inanimate objects.

SPAGHETTI TAGS—Spaghetti tags have 10-20 cm long plastic streamer tags attached to a metal dart that is designed to be imbedded about 2 cm under the skin (Evans et al., 1972). A spaghetti tag was applied with a lance to BR-2 at Marineland. Four forceful attempts were required before the tag-dart fully penetrated the skin. The manatee did not react overtly to the tagging process. The tag-dart was excised by veterinarians 3 mo later because the penetration wound appeared to be abscessed.

During field tests, 25 spaghetti tags were attached between 27 April and 21 June 1977, including 5 on captured manatees prior to release, 7 on free-ranging manatees in the Banana River, and 13 on free-ranging manatees in the Withlacoochee River. Eighteen of the free-ranging manatees were tagged with a thrown lance, 1 with a held lance, and 1 animal was tagged using a crossbow. The free-ranging animals were tagged either from shore or from a drifting boat at distances of 1-10 m.

In Brevard County, 18 spaghetti tags on free-ranging manatees were resighted near the KSC tagging sites up to 17 wk after the last tag was attached. The tags were difficult to see and too small for the individual numbers to be identified. In the Withlacoochee River, 5 animals were resighted with tags and 4 recognizable animals were known to have lost their tags. One (Field No. CR-70) was tagged twice in the Withlacoochee River and was closely examined by a diver on 2 occasions after both tags were lost. The original tag wound (28 May 1977) was healed, while the second tag wound (16 June 1977) was abscessed and still contained the tag dart when examined on 30 August 1977, almost 11 wk after the second tagging. Both tag wounds were fully healed when examined on 20 December 1977, 6 mo after the second tagging.

Manatee hide is very tough (Husar, 1977) and most marking attempts did not hit at an angle perpendicular to the body, which may have limited full penetration by the tag dart. Some of the tags probably were lost because the wounds failed to heal around the tag, causing abscesses, and eventually the foreign material was sloughed. Abscessed spaghetti tag wounds on small cetaceans have been reported by Irvine et al. (1982), but not by other authors (Sergeant and Brodie, 1969; Evans et al., 1972; Perrin, 1975).

PEDUNCLE STRAPS—In some instances, results from tests on captive animals were a poor indication of performance in the field. For example, at Marineland a tight-fitting 15.5-cm wide elastic band with a dummy transmitter attached was attached around the peduncle on BR-2. The elastic peduncle strap frayed and broke after 4 wk of attachment. In the Banana River, 3 of 5 elastic peduncle straps carrying sonic transmitters immediately slipped off the manatees as they swam rapidly away from the capture site (Table 1). The 2 other animals were relocated within 2 km of the capture site a maximum of 5 h (BR-8) and 3 da (BR-1) after tagging. BR-1 was found dead 4 da after release (Table 1); an autopsy did not determine cause of death.

As part of a cooperative study with the University of Minnesota, BR-10 and BR-12 were later fitted with nonelastic peduncle straps constructed from 1.5-cm wide machine belting encased in surgical tubing. The belts showed no wear and had not damaged the skin of the manatees when removed after 7 wk (just prior to release of BR-10 and BR-12).

Radio transmitters attached to machine belt peduncle straps have been used to study *T. manatus* in the St. Johns River (Bengtson, 1981) and in Crystal River (J. Powell, pers. comm.), and *T. inunguis* in the Amazon River (G. Montgomery, pers. comm.). We believe that use of the peduncle strap with radio-frequency transmitters would be limited to fresh water where transmissions will travel through the water. Radio signals are attenuated in salt water, and a peduncle-strap radio would seldom reach the surface to permit transmissions during the typical tail-down surfacing behavior of manatees.

TRANSMITTERS ON SPAGHETTI TAGS—Sonic transmitters attached to spaghetti tags were used to track 5 free-ranging manatees and 1 captured animal (Table 1). The free-ranging animals were tagged in the Withlacoochee River on 30 July 1977 (1 manatee), the warm-water effluent of the Florida Power and Light Company, Cape Canaveral Plant (FPL), Brevard County, Florida, in January 1978 (2 manatees), and the Blue Spring Run, Volusia County, in January and February 1978 (2 manatees). The captured manatee (BR-11) was tracked only briefly (Table 1). The first transmitter was taped to a FH-69 (0.2 cm x 20 cm) spaghetti tag and the others were taped to a larger experimental spaghetti tag (1 cm x 28 cm) designed for use on whales (J. Hall, pers. comm.). Corks were attached to the distal end to increase the buoyancy of the transmitter underwater, and 20-cm-long, colored plastic streamers were attached to increase the visibility of the tags. In general, signals from sonic-marked animals were lost easily and were difficult to relocate unless direction of movement was anticipated. The signals often were attenuated by underwater obstructions such as weed beds or sand bars, and the range varied between 25-400 m.

Sonic transmitter-spaghetti tags remained attached to the manatees at Blue Spring for 3 da (BS-13) and 11 da (BS-6; Table 1). Sonic-tagged manatees were relocated in Blue Spring Run for up to 52 consecutive hours (Fig. 1). The animals left the spring run during both day and night-time hours and sometimes fed nearby on floating water hyacinths (*Eichhornia crassipes*), but usually they moved north to Lake Beresford. The focus of manatee activities around the spring run is consistent with previous reports (Powell and Waldron, 1981). Although based on limited observation time, the nocturnal movements of BS-13 out of the run (Fig. 1) are noteworthy because little is known about manatee activities at night.

When away from Blue Spring the tagged manatees moved in the river at speeds of 2 to 5 km/h. Manatee BS-6 moved as much as 8 km in 2.6 h and 4 km in 1 hr against the 3.7 km/h current of the St. Johns River. Diving intervals for cruising manatees were recorded on 10 February and averaged 3 min 48 s per dive for BS-6 (SE ± 38.9 s; $n = 22$) and 4 min 12 s per dive (SE ± 36.8 s; $n = 15$) for BS-11, an untagged but recognizable manatee that was moving with BS-6. Activities of manatees outside Blue Spring Run were not usually observed because of poor water clarity.

The results of sonic tracking studies at FPL are unclear. The longest verified attachment was at least 11 da, and intermittent relocations of that animal at FPL (BR-9; Table 1) suggest that it may have remained absent from the warm effluent for several days. It also is possible, however, that the animal returned to the site between searches or was missed during searches.

A manatee with a radio transmitter taped to a spaghetti tag was tracked for 8 h in the St. Johns River before the signal was lost (BS-X, Table 1). The spaghetti tag and transmitter separated from the dart tip and were recovered 4 da later.

SUTURE ATTACHMENT—One and 3-cm deep suture attachments were tested on BR-10 at Marineland during 3 experiments. Each test was evaluated before the next commenced. A 5 cm x 5 cm x 1 mm stainless steel plate was attached to the animal's skin, dorsal to the scapula region with 8, 1-cm deep sutures, using a combination of Vetafil-Bengen, Cromic C nylon in PVC tubules, and stainless steel sutures. All sutures sloughed loose within 26 da, with stainless steel sutures holding longest. A pair of similar-sized plates, each held with 8, 3-cm deep stainless steel sutures, pulled loose after 14 wk when the animal struggled in a stretcher. A 12 cm x 4 cm x 2 cm wood block, attached posterior to the skull, was held anteriorly and posteriorly

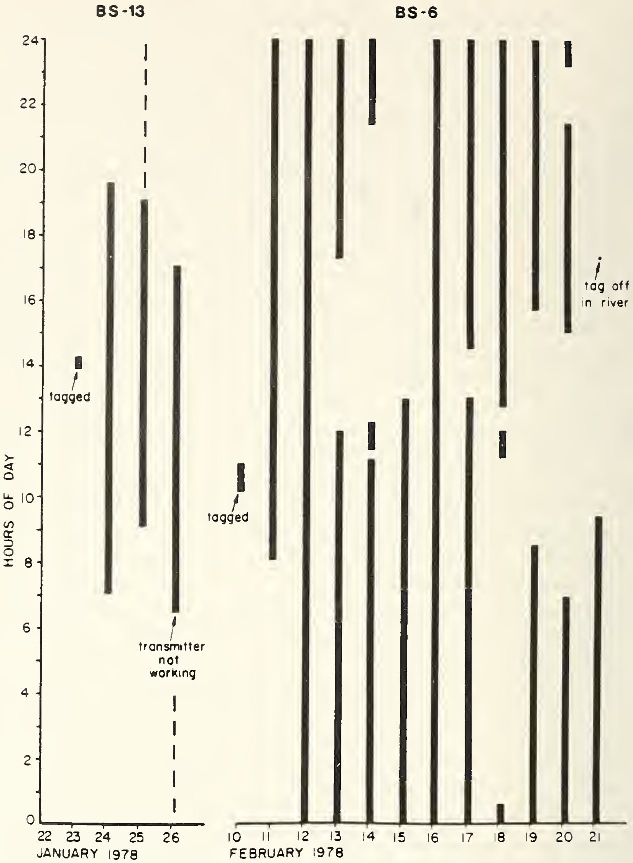

Fig. 1. Use of Blue Spring Run by sonic-tagged manatees. Solid lines indicate time periods when manatees were present in the spring run. Dashed line indicates that tag failed to function sometime after the animal left the spring run.

with single 3-cm deep sutures of nylon, silk and steel wound together. A 20-cm long tether and wood float was connected to the block to determine if a floating antenna might reach the surface during respirations. The float reached the surface each time the animal was observed breathing (n = 96 dives).

Although longevity of suture attachment on captives may not directly relate to longevity on free-ranging animals, these results suggest that 3-cm deep stainless steel sutures may remain attached for several months. Sutures also have held transmitters on Weddell seals (Siniff et al., 1971), a gray whale (Sweeney and Mattsson, 1974), and alligators (Smith et al., 1974).

On 14 August 1978, six stainless steel sutures, 1-cm deep, were placed in the skin posterior to the skulls of BR-10 and BR-12. Different transmitter packages, built to test transmission characteristics of each design from a free-ranging manatee, were attached with the sutures prior to the release of the animals. The transmitter on BR-10 had a 30-cm long stiff whip antenna and was mounted on a padded, stainless steel plate attached directly to the manatee. The transmitter on BR-12, encased in foam to make it buoyant, had a 30-cm long flexible antenna and was attached to a padded stainless steel plate by a 30-cm long stainless steel tether. The plates were sutured behind the skull to maximize chances that the antenna would break the surface of the water during respirations.

After release, BR-10 and BR-12 were radio tracked continuously from boats for 44 h and then relocated at intervals during the remaining life of each transmitter. Positions determined by triangulation from over 1 km away were visually verified on 6 occasions to be within approximately 100 m of the estimated position. Except to determine positions, close approach was avoided to prevent influencing the behavior of the animals.

BR-12 was located frequently in shallow areas ($\approx$ 1-m deep) within 8 km of the release site and often was relocated within 1 km of the last known location on the previous day. The manatee was relocated on 16 of 19 da from 16 August until 4 September 1978, after which transmissions were not received.

BR-10 was tracked up to 34 km away from the release site and moved as much as 10 km in 4 h. This animal was relocated on 25 of 28 da from 16 August through 13 September 1978. Signals were received intermittently from 13-17 September, but positions could not be determined, and on 19 September the animal was sighted without its transmitter. Small marks, apparently where the sutures had opened, were observed from a distance of approximately 10 m, but no obvious signs of infection or swelling caused by attachment were visible. The animal was later recognized by a freezebrand twice during the summer of 1979, on 1 January 1980, and on 11 May 1981 by the lockmaster at the Canaveral Barge Canal locks in the Banana River.

Cumulative data thus indicate that BR-10 was in Brevard County during at least the summers of 1977, 1979, and 1980, and during part of the winter of 1979-80. Hartman (1979) suggested that manatee movements during the warm season are irregular, with animals spending days or weeks in localized areas before moving to a new location. Individual movements have been documented previously only when recognizable individuals returned to warm water refuges during winter (Moore, 1956; Hartman, 1979; Powell, 1981; Powell and Waldron, 1981; Shane, in press).

Intervals between transmissions were interpreted as dive times because radio signals are severely attenuated in salt water (Ireland and Kanwisher, 1978), and a similar approach has been used to study radio tagged cetaceans (see Leatherwood and Evans, 1979). Transmissions from BR-10 and BR-12 were only received when the antennas reached the surface (n = 81 observations). Dive times averaged 3 min 23 s (SE = ± 8.3; n = 850) for BR-10, and 3 min 27 s for BR-12 (SE = ± 14.7; n = 252). Frequency distributions of dive intervals during 4 h periods (Fig. 2) varied significantly ($P = < 0.01$; 2-way contingency tables; Dixon and Brown, 1977) with time of day. Long dives (> 9 min) interspersed with short dives (< 1 min) were common during the afternoon (1200-1600 hr), while shorter dives (1-5 min) were most common at night (2000 to 0800 hr; Fig. 2). The patterns of long afternoon dives may be comparable to the afternoon rest periods of manatees reported by Bertram and Bertram (1964) and Parker (1922), although extensive studies by Hartman (1979) and Reynolds (1977; 1981a) suggest that well-defined diurnal rest periods are not apparent.

The tracking results appear to be useful to study manatee activity cycles, but because the animals were only occasionally observed while data were collected, we cannot verify that the antennas reached the surface and transmitted on each respiration. Respiratory activity while the animals were surfaced is also unknown. Even at close range (≤ 50 m), however, signals were not received when the antennas were submerged, and we, therefore, feel that the intervals between transmissions do represent dives.

Maximum dive times as indicated by intervals between transmissions were 31 min 5 s for BR-10 and 27 min 6 s for BR-12, and are the longest yet reported for manatees. The maximum dive time observed by Parker (1922) was 16 min 20 s, and Reynolds (1977) reported a dive of "nearly 24 minutes". Anecdotal accounts by fishermen and hunters suggest that 30-min dives by frightened manatees are possible (Parker, 1922; Barrett, 1935).

Time at or near the surface, indicated by continuous transmission, was 7.1% and 30.3% of the tracking time for BR-10 and BR-12, respectively. During transmissions, BR-12 was within 60 cm of the surface (the tether-antenna tip length), whereas BR-10 was always within the 30-cm antenna length from the surface. Average surface-time was 15.0 s (SE ± 2.3; range 1-868 s; n = 876) for BR-10, and 83.1 s (SE ± 26.22; range 1-4667 s; n = 273) for BR-12. Because manatees usually require only about 2-5 s to respire, these results indicate that the radio tagged manatees often remained within 30-60 cm of the surface when not breathing. For example, BR-10 was observed 3 times while apparently feeding against the shoreline with its back awash, and BR-12 was repeatedly observed at the surface in shallows (≈ 1-m deep) next to deeper dredged areas. Transmissions were received relatively more frequently from 0000-0400 hr for BR-10 and 0400-0800 hr for BR-12 (Table 2). Because manatees are vulnerable to collisions with motor boats (Moore, 1956; Hartman, 1979; Brownell et al., 1981) more information about near-surface activities would be useful for development of conservation and management plans.

Activities of telemetered manatees near the surface might also be valuable to assess the accuracy of aerial surveys over turbid waters. An

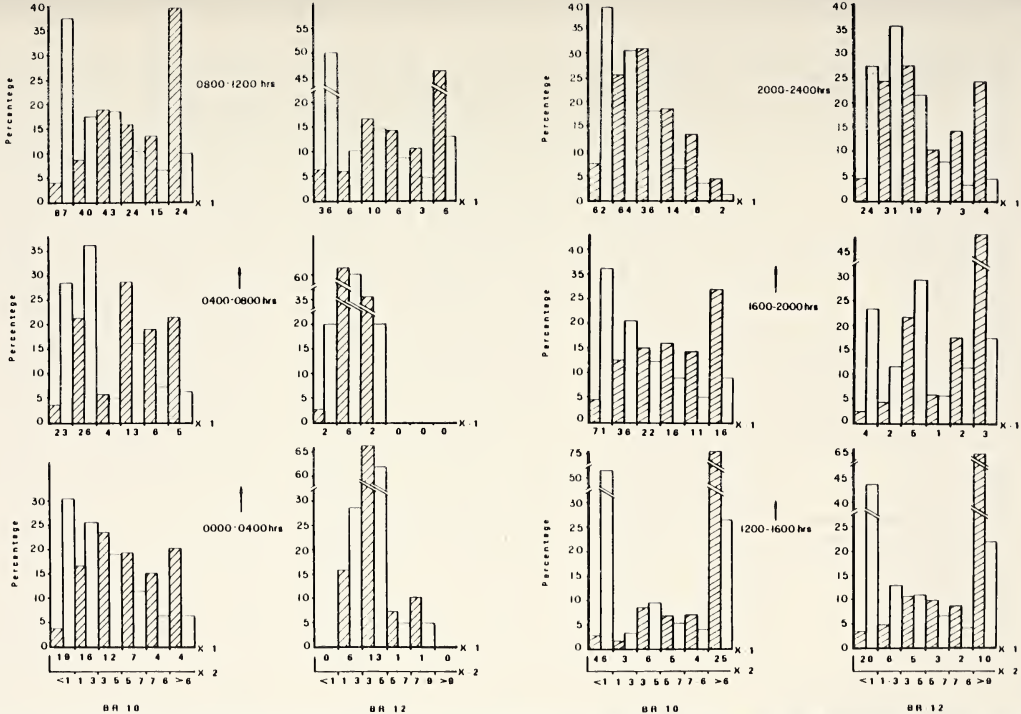

FIG. 2. Dive intervals for radio marked manatees BR-10 and BR-12. Histograms indicated percent of dives of different length (open bars) and percent of total time submerged during dives of different lengths (closed bars). Numerals below axis X-1 represent number of dives. Numerals below axis X-2 represent length of dive in minutes.

TABLE 2. Tracking time at or near the surface for radio tagged manatees in Brevard County: August and September, 1978. Percentages are calculated from tracking time for each time period.

	BR-10		BR-12	
Time Period	% of Tracking Time at Surface	Tracking Time	% of Tracking Time at Surface	Tracking Time
0000-0400	17.6	2 h 11.9 min	2.0	1 h 17.8 min
0400-0800	8.5	4 h 40.1 min	75.4	1 h 12.1 min
0800-1200	1.9	15 h 14.7 min	38.4	6 h 23.8 min
1200-1600	6.5	8 h 11.2 min	34.5	5 h 8.3 min
1600-2000	6.3	10 h 14.7 min	12.0	1 h 41.7 min
2000-2400	12.7	9 h 7.1 min	18.3	5 h 4.1 min

unknown number of manatees are not seen during aerial surveys and ground truth techniques are unavailable (Hartman, 1974; Irvine and Campbell, 1978). Knowing the location and surfacing patterns of telemetered animals during aerial surveys may offer a means to assess sighting efficiency and perhaps to develop correction factors to estimate the number of manatees not observed.

SUMMARY AND CONCLUSIONS—Mark-resighting results were limited because the marks were either not durable or not highly visible. Marks with Paintstiks and aerosol paint are short-lived, and use of aerosol paint also startled the animals and polluted the water. Spaghetti tags were often lost due to poor dart penetration, and caused abscesses on some animals.

Freezebrands were the most potentially useful marks because of their longevity, but application requires capture and handling of each animal. A free-ranging manatee was identified at a distance of about 15 m up to 45 mo after branding. Applied marks may be largely unnecessary in clear-water habitats because many manatees have distinctive scars from collisions with boats.

Radios were more effective for tracking manatees than sonic transmitters. Movements of telemetered manatees in Brevard County were generally localized, but 1 animal moved as much as 10 km in 4 hr. Nonelastic peduncle straps were the most practical transmitter attachment method for use in fresh water where transmissions carry through the water. In saline habitats, where the antenna must reach the surface of the water to transmit effectively, suture attachment of the transmitter posterior to the skull was effective, but needs further testing to determine longevity of sutures.

Telemetered information could be useful for management needs. Movement data could indicate habitat use patterns and help determine if sanctuaries can be established for manatees. Surfacing and near-surface behaviors might indicate activity patterns and when and where manatees are particularly vulnerable to collisions with boats.

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APPENDIX 1

PRODUCTS MENTIONED IN THE TEXT*

Vitamins—Pacific Research Laboratory, Ltd., El Cajon, CA.
Freezebrands—Hawkeye Castings, Inc., Manchester, IA.
Aerosol Paint—Lenmar, Inc., Baltimore, MD.
Paintstiks—Lake Chemical Co., Chicago, IL.
Spaghetti tag—Floy Tag Corp., Seattle, WA, Model FH-69.
Elastic Belt Tags—Solace Enterprises, Anchorage, AK.
Sonic (belt) transmitters—Dukane Corp., St. Charles, IL, Model N15B218; 30-45 KHZ; 15 cm x 10 cm x 5 cm.
Sonic transmitters (on spaghetti tags)—Smith Root, Inc., Vancouver, WA; 50-64 KHZ; Model SR-69: 5.7 cm x 14 mm dia; Model SR-50: 8.1 cm x 19 mm dia.
Sonic receivers—Smith Root, Inc., Vancouver, WA; receivers: Model TA-25; hydrophones: Model TA-25.
Radio transmitters and receivers—Cedar Creek Bioelectronics Laboratory, Bethel, MN; transmitter: 164 MHZ; 10 cm x 2.5 cm dia.; receiver; Yagie null-peak antenna.
Suture material: Vetafil-Bengen: S. Jackson, Inc., Washington, DC; Cromic C: Ethicon, Inc., Summerville, NJ.

*Mention of commercial products does not imply endorsement by the U.S. Fish and Wildlife Service.

EFFECT OF FROST ON A SUBTROPICAL *MUHLENBERGIA* PRAIRIE IN SOUTH FLORIDA

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Abstract: *Minimum temperatures of less than 0°C were recorded on 2 nights during January, 1981 in Taylor Slough within the Everglades National Park. Resulting frost severely damaged 16 plant species, did moderate damage to 12 species, and had no apparent effect on 12 species. The effect was a minor short-term impact on plant species with a more pronounced impact on live and dead biomass. Measurements pre- and post-frost indicated a significant 25% decrease in live biomass with a corresponding 12% increase in the dead component. Seasonally occurring frosts can have a significant impact on fuels of less than 6 mm size, and may influence fire behavior.*

Although freezing temperatures are not unprecedented in Everglades National Park, the opportunity to measure effects of low temperatures on vegetation is an unusual one. Just prior to 2 nights when less than 0°C temperatures occurred, vegetation biomass had been sampled in *Muhlenbergia* prairie on the west edge of Taylor Slough (Fig. 1). By resampling biomass immediately after the freeze, a measure of freeze impact on species and on the amount of live/dead biomass was possible.

Temperatures in Taylor Slough dropped below 0°C for 5 hrs on 13 January and for 2 hrs on 19 January 1981. Minimum temperatures at the nearby Royal Palm Ranger Station were −3.3°C and −1.7°C, respectively, on these 2 nights. The *Muhlenbergia* prairie where this study was conducted is characterized by shallow marl soils over Miami oolite limestone, pinnacle rock and solution holes. It is the highest and driest of the slough's graminoid communities with a short late summer hydroperiod of 2-4 mo (Olmsted et al., 1980). This relatively short hydroperiod results in a dry soil surface during most of the dry season. Soils were dry at the time of the frost. Dominant plant species are graminoids, *Cladium jamaicense*, *Rhynchospora tracyi*, *Muhlenbergia filipes*, and *Schizachyrium rhizomatum*. A periphyton mat covers the soil.

Methods—Pre- and post-frost biomass samples were collected at 3 treatment areas in the *Muhlenbergia* prairie fire ecology study plots. These were the Control (C), July annual (J1), and July 3 year (J3) treatments, used to examine various fire effects on prairie habitat (Fig. 1). The prairie study site is located north of the main park road and about 1 km northwest of the Royal Palm road junction.

The 2 July treatment areas were burned during July 1979 and both were 18 mo post-fire in age. No accurate date for the last fire on the control plot has been found, but it was estimated to have occurred about 10 yr ago.

Biomass samples were collected from each treatment at 2 vegetation plots and a mammal plot. Pre-frost samples were collected randomly at the northwest corner of each of these plots,

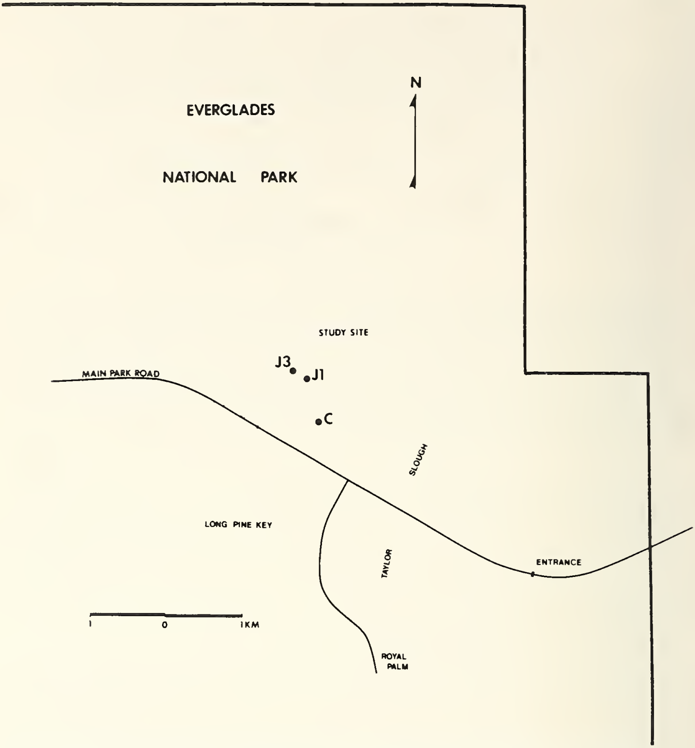

FIG. 1. Location of fire ecology study plots within the Everglades National Park.

with post-frost samples collected at the northeast corner. Pre- and post-frost samples are about 15 m apart at the vegetation plots, and 40 m apart at the mammal plots.

Pre-frost sampling as part of the prairie fire study was completed during 15-18 December 1980, in the Control treatment, and 5-9 January 1981, in the July treatments. All post-frost samples were collected 3-10 February 1981, following the 13 and 19 January frosts.

Biomass of all above-ground plant parts, except periphyton, was collected by clipping at ground level. Collections were placed in plastic bags, returned to the laboratory and sorted into 4 categories: (1) live sawgrass *(Cladium);* (2) dead sawgrass; (3) live "other," i.e., everything alive except sawgrass; and, (4) dead "other." The samples were dried in a convection oven at 70°C for 3 da, and weighed to the nearest tenth of a gram.

While in the study area, observations were made of frost impact on individual plant species. Notes were general, listing whether a species was impacted severely, moderately, or not at all. These criteria are defined as follows: (1) Severe: All above-ground plant parts apparently killed, (2) Moderate: Some damage apparent to above-ground parts, but not complete, and (3) No Impact: No discernible evidence of frost damage. Plant names follow Avery and Loope (1980).

FROST DAMAGE TO INDIVIDUAL SPECIES—Frost impact on species observed during late January and early February is in the Appendix. Sixteen species were recorded with severe frost damage, 12 with moderate damage, and 12 as having no apparent damage. Prairie species not listed were either not observed or apparently dormant at the time of the frost.

Change in live/dead biomass—Biomass (gm/m^2) was measured to determine if a significant change in weights occurred following the frosts. Means and standard deviations for the 4 categories pre- and post-frost are in Table 1. The t-test for 2 sample means showed no significant difference between the pre- and post-frost biomass samples. However, the samples showed a consistent post-frost decrease in the live "other" category, and a consistent increase in dead "other" (Table 1). The variability due to standing crop difference was then eliminated by transforming the data to percentage of total sample (Table 2). Live biomass was used because the frost effects would be most pronounced on this component. A significant change in the live component would have to occur before a change occurred in the dead component which accumulates over time.

A significant decrease was measured in the live "other" category following the frost (Wilcoxon-Mann-Whitney Test: Control, $z = 2.96$, $P = .002$; J1, $z = 2.08$, $P = 0.019$; J3, $z = 2.87$, $P = 0.002$). The same test applied to live sawgrass pre- and post-frost showed no significant difference between the two time periods (Control, $z = 0.13$, $P = 0.448$; J1 $z = 1.02$, $P = 0.154$; J3, $z = 0.49$, $P = 0.313$). A decrease in live "other" biomass of 27% in the J1 and J3 plots to as much as 42% in the control plot occurred during the frosts.

Table 1. Pre- and post-frost live/dead biomass (g/m^2) by category.

	Cladium				Other				
	Live		Dead		Live		Dead		
Treatment	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	Total
Pre-frost Control	35.3	35.4	88.3	73.4	64.9	46.4	194.6	104.7	383.1
J1	9.9	9.2	11.9	12.4	45.7	14.4	80.8	23.0	148.3
J3	8.4	9.9	11.4	14.3	46.5	14.0	73.5	26.2	139.8
Post-Frost Control	25.1	15.5	95.0	59.6	44.5	17.0	277.8	102.7	442.4
J1	10.7	18.7	9.8	11.7	34.1	8.8	94.2	26.7	148.8
J3	6.6	4.6	10.3	7.4	35.7	11.7	89.3	26.4	141.9

$\bar{x}$ = mean, s.d. = standard deviation, and n = 9 per treatment. J1 and J3 refer to plots burned each year and every 3rd year during July.

Table 2. Live *Cladium* and "Other" biomass (percent of total category sample).

	Control				J1				J3			
	Pre-frost		post-frost		pre-frost		post-frost		pre-frost		post-frost	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Cladium	21.9	7.4	24.6	13.3	46.3	26.2	44.2	13.1	35.9	18.2	42.0	11.0
"Other"	24.4	4.9	14.4	4.9	36.2	9.3	27.0	5.6	39.1	5.8	28.8	5.8

$\bar{x}$ = mean, s.d. = standard deviation and n = 9 per treatment. J1 and J3 refer to plots burned each year and every 3rd year during July.

Discussion—Frost effects on forbs was immediate and obvious in a few hours. Forbs most affected by freezing temperatures were those with an erect posture such as *Crinum*, *Eupatorium*, *Ipomea*, *Melanthera* and *Pluchea*. Plants with a procumbent or rosulate habit, such as *Centella* and *Samolus* were least affected. Impact on the palm, *Serenoa repens*, was restricted to the death of nearly all flowering inflorescences.

Frost effect on graminoids was less obvious than on forbs because they took time to brown, but they remained upright. Graminoids most severely damaged were *Rhynchospora tracyi* and *Dichanthelium*. *Caldium* *jamaicense* (sawgrass) and *Muhlenbergia filipes* showed no apparent damage. Hilsenbeck (1977) reported an impact on *Cladium* and *Muhlenbergia* when a severe cold front of much greater duration invaded south Florida on 20 January 1977, and when a temperature of −4.5°C was recorded at the Royal Palm Ranger Station (Rose and Rosendahl 1979). Damage to sawgrass and *Muhlenbergia* may have occurred in 1981, but the effect was minimal.

Long-term frost impact on herbaceous and graminoid species appears to be minor. Phenology data from January 1978 showed no species at peak flower and only 1 at peak fruit (Loope, 1980). Two species Loope recorded as flowering were *Solidago stricta* and *Aster dumosus*, which we observed being only slightly and not at all impacted by the 1981 freeze. By late March 1981 observations showed most species recovered. Hilsenbeck (1977) reported similar findings following the 1977 frost. An important frost effect is the curing of graminoids which increases fuels and reduces fuel moistures. This results in easier ignitions, faster rates of fire spread, and fires of greater intensity. Small (1918) recorded winter prairie fires of increased severity after a freeze in February 1917 killed above-ground plant parts in Taylor Slough.

A major problem in determining if the change in live "other" biomass was due to frost is the chance of a seasonal change having occurred that is correlated with water levels, rainfall, or normally lower temperatures. No area on the prairies was frost-free to act as a control. Rainfall and water levels were slightly lower during 1981 than for the previous year (Table 3), but both water levels and rainfall followed a similar pattern over the 2 yr.

TABLE 3. Comparison of 1980 and 1981 rainfall records at Royal Palm Ranger Station and water levels at Taylor Slough bridge.

	1979-80	1980-81	Average for Period of Record
Rainfall	*(cm)*	*(cm)*	*(cm)*
December	3.43	3.40	3.53
January	2.51	0.84	4.09
Water Levels	*(m msl)*	*(m msl)*	*(m msl)*
December 18-20	0.90	0.88	0.64
January 17-19	0.71	0.68	0.59
January 31-February 3	0.89	0.65	0.67
February 8-13	0.80	0.61	0.60

*Monthly Hydrology Synopsis, Everglades National Park, Dec. 1979, Jan., Feb., Dec. 1980, Jan. 1981. South Florida Res. Cent., Everglades Natl. Park, Homestead, Florida.

Pre-frost data from the control treatment (estimated at 10 yr post-fire) indicated biomass had reached an equilibrium between rate of production and rate of decomposition. If the live/dead biomass in the Control treatment had reached equilibrium and did not vary significantly without frost, then fuel samples collected during 1979-80, a frost-free period, could be used as a control (Table 4). This assumes that seasonal changes were the same for the

TABLE 4. Percent of the total "Other" live biomass in the control treatment.

Date	$\bar{x}$	s.d.	n
December 1979	20.5	2.62	2
February 1980	20.8	2.65	7
April 1980	22.6	6.87	10
August 1980	20.1	3.57	12
December 1980	24.4	4.89	9
Mean–Dec. 1979-80	21.9	4.94	40
February 1981	14.4	4.92	9

x = mean, s.d. = standard deviation, n = number of samples.

1979-80 and 1980-81 sampling interval and that frost was the only major difference.

An analysis of variance (unequal subclass sizes) with all sample periods yielded a significant difference between sample means ($F = 5.54$; 4,42 d.f.; $P < 0.005$). The difference between the means was compared using a t-test (Snedecor and Cochran, 1980). No significant differences were detected between the pre-frost samples (at 5% level, 42 d.f.; differences in means 4.57). However, the February 1981 sample was significantly different from all previous samples. This indicates the mean of all pre-frost samples is a good estimate of the live/dead biomass inherent at equilibrium and that the February 1981 sample is different due to the frost effects.

We conclude that the frosts of 13 and 19 January had a minor short-term impact on prairie plant species and a more pronounced impact on live and dead biomass. The greatest impact on biomass was the decrease in total live biomass (*Cladium* plus "other") of 22-27%. The resulting increase in total dead biomass was 10-14%, where the frost effect was dampened by accumulated litter. Shift in biomass from live to dead amounted to 12 gm/m^2 in the 18 mo treatments and 27 gm/m^2 in the old 10 yr treatment at equilibrium. Seasonally occurring frosts can have a significant impact on fuel compositions in the *Muhlenbergia* prairies—a factor that can influence fire behavior.

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APPENDIX

Frost impact on prairie plant species; Forb (F) and graminoid (G)

Severe		Moderate		No Impact	
Chiococca parviflora	F	*Aletris bracheata*	F	*Aster adanatus*	F
Crinum americanum	F	*Aristida purpurascens*	G	*Aster dumosas*	F
Dichanthelium dichotomum	G	*Cirsium horridulum*	F	*Aster teniufolius*	F
Heliotropium polyphyllum	F	*Eleocharis cellulosa*	G	*Buchnera floridana*	F
Hymenocallis palmeri	F	*Eragrostis elliottii*	G	*Centella asiataca*	F
Ipomoea sagittata	F	*Linum medium*	F	*Cladium jamaicense*	G
Melanthera augustifolia	F	*Panicum* sp.	G	*Dichromena colorata*	G
Mikania scandens	F	*Piriqueta caroliniana*	F	*Erigeron quercifolius*	F
Oxypolis filiformis	F	*Schizachyrium rhizomatum*	G	*Helenium vernale*	F
Phyla nodiflora	F	*Serenoa repens*	Palm	*Muhlenbergia filipes*	G
Polygala grandiflora	F	*Solanum donianum*	F	*Samolus ebracteatus*	F
Pluchea rosea	F	*Solidago stricta*	F	*Schoenus nigricans*	G
Rhynchospora tracyi	G				
Rhynchospora divergens	G				
Sagittaria lancifolia	F				
Utricularia subulata	F				

MODE OF LIFE OF *EXPUTENS OCALENSIS* (MALLEIDAE), A FLORIDA EOCENE PELECYPOD—(1)*David Nicol and* (2) *Douglas S. Jones,*

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Abstract: *Because of the great variability in outline of the valves of specimens of* Exputens ocalensis, *we think that this species was a nestler.*

Clark (1934), who described the genus *Exputens*, had a large number of specimens of *Exputens llajasensis* (the type species) from the middle Eocene of California. He noted great morphologic variability in the shells of this species and discussed the variation in the development of the ears or auricles, the prominence of the beaks and their location, and the variation in the outline of the valves. Clark came to the following conclusion as to the mode of life of *Exputens llajasensis*, based on this variability (1934, p. 271): "Most of the specimens of this species show irregularities in the surface of the shell. This, together with the variability in outline, the generally elongate shape, and the lack of any well-defined bysal [sic] notch, suggests that the species was a nestler."

Besides actual observation of nestling, distortion of the valves of a pelecypod has been used as a criterion that a species is a nestler (Nicol, in press). It has also been noted (Abbott, 1974) that some species of the family Malleidae, to which *Exputens* has been allocated, are nestlers. Neither MacNeil (1934), who described *Exputens ocalensis* as *Vulsella ocalensis*, nor Woodring (1973), who described *Exputens bostrychodes* from the late Eocene of Panama, said much about the variation of the shells in their species, although both of these paleontologists may have had small samples. Nicol and Shaak (1973) discussed only the geographic and stratigraphic ranges of *Exputens ocalensis*. This species is most abundant in the lower part of the Crystal River Formation in Florida (Nicol and Shaak, 1973), but Meeder (1976) also found this species in the Inglis Formation below the Crystal River, and he figured 1 of his specimens.

Of the many specimens of *Exputens ocalensis* in the invertebrate paleontology collection at the Florida State Museum, there are at least 34 well-preserved individuals, and this sample is adequate to show the variation in the outline of the valves of this species. We have illustrated 6 specimens (Fig. 1) that exhibit most of the variation in the shape of the valves present in *Exputens ocalensis*. Figure 1a is a typical small specimen with the auricle in front of the beak developed and an almost straight ventral margin. Shown in Fig. 1b is another small specimen with an auricle better developed and a more rounded outline of the valves than in Fig. 1a. Figure 1c is a specimen with a squarish outline and possessing no auricles. A larger, more elongate specimen is presented in Fig. 1d. This individual has a prominent ridge which runs from the beak toward the posterior ventral margin. One small auricle is present anterior to the beak, which is located not as far forward as it is in most specimens. Figure 1e portrays a greatly distorted specimen. The anterior end is swollen and enlarged. The ventral margin is arcuate, and the beak is located near the anterior margin. No auricles are present in this specimen. Figure 1f is a more flattened or less convex specimen. The auricles are present but not well-developed. The beak is located at approximately the anterior third of the dorsal margin, and the ventral margin is arcuate.

In general, the large specimens are more distorted and variable in the outline of the valves than are the smaller specimens. Most of the small specimens tend to be almost rectangular, and the auricles are commonly well-developed. The variations occur in the location of the beaks, development of the auricles, differences in height-length ratios, convexity of the valves, and the general outline of the valves. These are the kind of variations that Clark noted in 1934 in his description of *Exputens llajasensis*. Based upon the observations listed previously, we come to the conclusion that *Exputens ocalensis* was also a nestler. It probably lived in cracks and crevices among corals or in cavities in a hard substrate. If a byssus were present in the adult stage, it would have been poorly developed.

It is possible that not all species of *Exputens* were nestlers, and each species of this genus must be examined for presence or absence of distortion and variability in the outline of the valves.

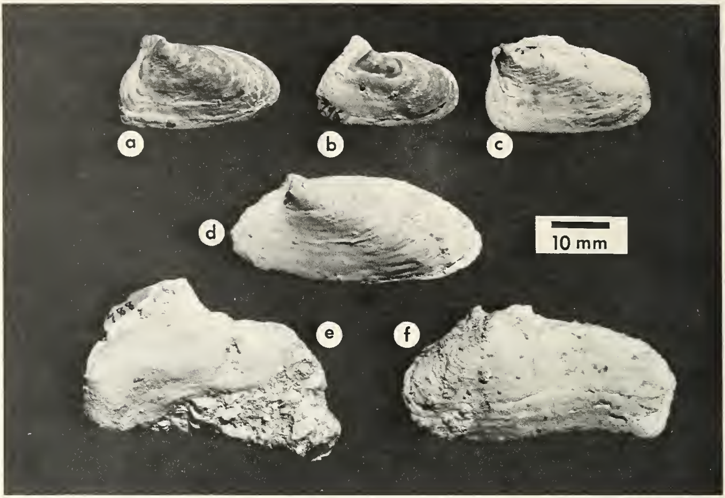

FIG. 1. All 6 specimens are exterior views of left valves of *Exputens ocalensis* (MacNeil) and are hypotypes housed in the invertebrate paleontology collection at the Florida State Museum. All specimens were collected in the lower part of the Crystal River Formation in Florida. Fig. 1a, catalog #3481, height 14.8 mm, length 28.0 mm, H/L = 0.53. Limestone quarry west of highway old 441 at south edge of Kendrick, Marion Co. Fig. 1b, catalog #5666, height 13.2 mm, length 25.0 mm, H/L = 0.53. Limestone quarry 3.4 mi. northwest of Mayo, Lafayette Co., on west side of highway 27. Fig. 1c, catalog #5667, height 15.2 mm, length 29.1 mm, H/L = 0.52. Limestone quarry 2.5 mi. northeast of Newberry, Alachua Co., on highway 235. Fig. 1d, catalog #3898, height 18.5 mm, length 43.3 mm, H/L = 0.43. Limestone quarry approximately 2.0 mi. northeast of Newberry, Alachua Co., on highway 235. Fig. 1e, catalog #5668, height 17.2 mm, length 41.9 mm, H/L = 0.41. Limestone quarry 5.0 mi. northeast of Newberry, Alachua Co., on highway 235. Fig. 1f, catalog #5669, height 22.4 mm, length 47.3 mm, H/L = 0.47. Limestone quarry 2.5 mi. northeast of Newberry, Alachua Co., on highway 235.

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THE CENOZOIC STRATIGRAPHIC RECORD OF PENINSULAR FLORIDA: HOW COMPLETE IS IT?

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Abstract: *The Cenozoic stratigraphic record of peninsular Florida is analyzed for the amount of time each unit represents, using techniques from Schindel (1980) and Sadler (1981). Calculations based on different assumed rates of sediment deposition show that each stratigraphic unit generally represents less time and becomes more incomplete as the record becomes younger. The early Paleogene ages and epochs are the best represented in the record and probably serve as the most promising strata for the study of long-term processes. Study of short-term processes (1,000 yr or less) may be more difficult and should be carried out with care because none of the units analyzed are even near 100% completeness at finer resolutions.*

Peninsular Florida lies on the sedimentary apron of the U.S. Coastal Plain and has an undisturbed and extensive stratigraphic record. This record has been described elsewhere (Cooke et al., 1943; Cooke, 1945; Applin and Applin, 1944; Toulmin, 1955; Puri and Vernon, 1964; and Chen, 1965) but certain aspects of it, such as how well it represents the time during which it was deposited, have been poorly understood. It now appears that reasonable estimates of the temporal representation and completeness of various thicknesses and types of rock can be estimated by using probable rates of deposition (Schindel 1980, Sadler 1981). In this paper I use the available data on the better understood parts of the stratigraphic record (i.e., the Cenozoic) of peninsular Florida to arrive at an estimate for the amount of time represented by each unit within it. With these estimates I will quantitatively show which intervals of geologic time are most completely recorded by sediments (and fossils) in Florida.

To calculate how much time is represented (a more precise definition of what is meant here will be discussed shortly) in a particular section, one needs a sound idea of the rate(s) of sediment deposition where the rock originated. Recently, two papers have been published which shed light on the problem on such rates. Schindel (1980) and Sadler (1981) have compiled a large sample of depositional rates for a variety of environments and noted that there is an inverse relationship for all environments studied between the rate of sedimentation reported by an investigator and the period of observation from which the rate was derived. That is, the rates of sedimentation reported decreased for each environment as the time span of observation increased. For carbonate platforms, sedimentation rates calculated from 100 yr intervals averaged higher (1,000 mm/1,000 yr) than those calculated from 1,000 yr intervals (500 mm/1,000 yr). These were, in turn, higher than those derived from 10,000 yr intervals (80 mm/1,000 yr; Schindel, 1980; Sadler, 1981). The reason for this probably is that as the period of observation increases, more intervals of non-deposition and/or erosion are averaged into the rate calculations which lowers the values.

This inverse relationship between rate of sedimentation and time span of observation has important ramifications for computations to determine how much time a given thickness of strata took to accumulate. In effect, it calls for a re-examination of what is meant by the concepts of time representation and completeness. Loosely used, time representation refers to the fact that a given thickness of strata in a given environment took a certain amount of time to accumulate and that interval of time is then represented by a sedimentary record in that area. Completeness can be generally defined as that portion of a given total time span (e.g., Eocene) that is represented by sediment or rock. Thus, a stratigraphic unit which is the result of sediment accumulation during at least part of each year for 100 yr represents 100 yr of time at a resolution of 1 yr. The unit would then be 100% complete for that 100 yr segment of time at that level of resolution. It would not be 100% complete for a resolution of smaller units of time, say 1 day, unless sediment accumulation occurred every day during that 100 yr interval.

Therefore, it becomes apparent that the concepts of temporal representation and completeness cannot be fully understood without reference to the level of resolution at which they are interpreted. Because the rates of sedimentation used to calculate values for temporal representation and completeness vary with the time span of observation, then the values obtained are valid only for a level of resolution which is equal to that of the time span of observation used. For example, because the above-mentioned sedimentation rate for carbonate platforms averages about 1,000 mm/1,000 yr when calculated from known 100 yr intervals, then whatever values are obtained for a given carbonate unit's temporal representation and completeness are applicable only for a resolution of 100 yr. This assumes that there are no gaps (i.e., time unrecorded by sediment) in the strata analyzed greater than the level of resolution used. The value for completeness would be the percent of all the time intervals forming the time span of the strata analyzed which saw some accumulation of sediment (i.e., temporal representation/time span of unit). Thus, a 100% complete section at the 100 yr level of resolution is one in which no gap exists between the upper and lower time boundaries of the strata which is longer than 100 yr.

MATERIALS AND METHODS—Quantification of the temporal representation and completeness of a stratigraphic unit is straightforward. The amount of time which a given thickness of section represents is calculated by dividing the thickness by the appropriate rate of sedimentation. The rate of sedimentation is based on the depositional environment and the desired level of resolution. The rates for the major depositional environments can be reasonably approximated from Schindel (1980) or Sadler (1981); the latter compilation is much larger.

As an example consider a 500 m thick section of limestone. The amount which this represents at a resolution of 100 yr would be:

$2 \times 500 \text{ m} \div 1{,}000 \text{ mm}/1{,}000 \text{ yr} = 1 \text{ million yr}$

given the average sedimentation rate for carbonate platforms at this resolution. The thickness is multiplied by 2 because the rates used are generally computed from unconsolidated sediments, whereas lithified strata undergo a reduction of about 50% during the lithification process (Schindel, 1980).

As noted, completeness is calculated by dividing the amount of time represented by the unit by the actual time span which passed between the upper and lower boundaries of the unit. Thus, had the above-mentioned 500 m of limestone been deposited over the course of the entire Late Eocene (some 5.8 million yr) then it would have been

1 million yr/5.8 million yr = 17%

complete at a 100 yr level of resolution. That is, in that area sediment deposition occurred in only 17% of all the 100 yr intervals making up the Late Eocene.

Table 1 outlines the major Cenozoic stratigraphic units of peninsular Florida, gives the epoch to which each is assigned, and shows the duration of each epoch and age based on one of the latest paleomagnetic dating schemes (LaBrecque, Kent, and Cande, 1977). It also lists the maximum thickness of each unit and the general lithology. The maximum thickness is used in all calculations to provide an estimate of how much time is represented at best. The data are mainly from subsurface samples in South Florida where the strata are thickest, except for the Alachua Formation which occurs only in the north and central portions of the peninsula (Puri and Vernon, 1964).

Only the major stratigraphic units are listed and analyzed here. Localized and/or poorly defined units (such as "Plio-Pleistocene sands") are omitted. To some extent, the 2 Miocene units, the Hawthorne and the Alachua Formations, are problematic because neither is nearly as laterally continuous as the earlier, carbonate units. Further, their environments of deposition and even ages are controversial. I consider the Hawthorne Formation to be of Miocene age, which is in agreement with most workers (see Williams et al., 1977 for a review). The Alachua Formation has recently been assigned to the Miocene, on the basis of vertebrate fauna (Webb et al., 1981), though many earlier workers dated it as Pliocene (Williams et al., 1977). In spite of their troublesome features, these 2 formations are included here because Neogene time is very poorly represented in Florida and, despite their drawbacks, these units are probably the most complete in peninsular Florida for that period.

RESULTS AND DISCUSSION—Table 2 shows the computed amount of time represented by each of the major stratigraphic units of peninsular Florida as calculated from the maximum thickness values in Table 1 and the rates of sedimentation listed at the bottom of Table 2. The lithostratigraphic units (formations) are listed along with the chronologic units (epochs and ages) to which they belong. The formations in Florida are apparently assignable to only 1 epoch or age each. Environments of deposition reflect a dominance of carbonate sedimentation. Throughout the Paleocene the area was essentially a shallow marine platform (Puri and Vernon, 1964; Chen, 1965; Cheetham, 1963; Williams et al., 1977). During the Neogene, deposition became more terrestrially influenced, as seen in the increasing dominance of siliciclastic and localized sedimentation as exemplified by the Hawthorne and Alachua Formations. These formations show evidence of both marine and non-marine environments of deposition and are lithologically complex and heterogeneous (Williams et al., 1977). Webb et al., (1981) conclude that the Hawthorne Formation is mainly marine while the Alachua Formation is mainly non-marine. In accordance with this conclusion and in light of other data (Puri and Vernon, 1964; Williams et al., 1977), I consider the Hawthorne Formation to have originated in an environment that is best described as alternating between or transitional to Schindel's (1980) deltaic and coastal wetland environments. The rates of sedimentation used here are interpolated from between the rates averaged for these two. I consider the Alachua For-

Table 1. Basic outline of the major Cenozoic stratigraphic units of peninsular Florida.

Epoch	Duration[1](m.y.)	Chronostrat. Unit	Lithostrat. Unit	Max. Thickness[2](m)	Lithology
Miocene	17.4	Choctawhatchee Stage	Alachua Fm	31	clay/sand
		UNCONFORMITY			
Miocene	17.4	Alum Bluff Stage	Hawthorne Fm	213	phosphatic clay/sand
		UNCONFORMITY			
Oligocene	15.6	Vicksburg Stage	Suwannee Fm	195	carbonate
		UNCONFORMITY			
L. Eocene	5.8	Jackson Stage	Crystal River Fm	95	carbonate
L. Eocene	5.8	Jackson Stage	Williston Fm	15	carbonate
L. Eocene	5.8	Jackson Stage	Inglis Fm	46	carbonate
L. Eocene Total	5.8			156	
		UNCONFORMITY			
M. Eocene	5.4	Claiborne Stage	Avon Park Fm	244	carbonate
M. Eocene	5.4	Claiborne Stage	Lake City Fm	302	carbonate
E. Eocene	5.8	Wilcox Stage	Oldsmar Fm	384	carbonate
Eocene Total	17.0			1086	
		UNCONFORMITY			
Paleocene	10.0	Midway Stage	Cedar Key Fm	646	carbonate

[1] From LaBrecque, Kent, and Cande, 1977.
[2] From Puri and Vernon, 1964 and Chen, 1965.

TABLE 2. Time representation and completeness of the major Cenozoic stratigraphic units of peninsular Florida.

Formation Epoch	Environment of Deposition[1]	Amt. of Time Rep. (10^6 yr) at Levels of Resolution[2]				Completeness at Levels of Resolution			
		10^0yr	10^2yr	10^3yr	10^4yr	10^0yr	10^2yr	10^3yr	10^4yr
Alachua Miocene	Fluvial	0.00069	0.010	0.062	0.089	0%	0%	0%	1%
Hawthorne Miocene	Deltaic-Coastal Wetland	0.00085	0.043	0.085	0.53	0%	0%	0%	3%
Miocene Total		0.0015	0.053	0.15	0.62	0%	0%	0%	4%
Suwannee Oligocene	Shallow Marine Bank	0.039	0.39	0.78	4.9	0%	3%	5%	31%
Crystal River L. Eocene	Shallow Marine Bank	0.019	0.19	0.38	2.4	0%	3%	7%	41%
Williston L. Eocene	Shallow Marine Bank	0.0030	0.030	0.060	0.38	0%	1%	1%	6%
Inglis L. Eocene	Shallow Marine Bank	0.0092	0.092	0.18	1.2	0%	2%	3%	20%
L. Eocene Total		0.031	0.31	0.62	4.0	1%[3]	5%[3]	11%	69%[3]
Avon Park M. Eocene	Shallow Marine Bank	0.049	0.49	0.98	6.1	1%	9%	18%	100%
Lake City M. Eocene	Shallow Marine Bank	0.060	0.60	1.2	7.6	1%	11%	22%	100%
M. Eocene Total		0.11	1.1	2.2	14	2%	20%	41%[3]	100%

TABLE 2. Continued.

Formation Epoch	Environment of Deposition[1]	Amt. of Time Rep. (10^6 yr) at Levels of Resolution[2]				Completeness at Levels of Resolution			
		10^0yr	10^2yr	10^3yr	10^4yr	10^0yr	10^2yr	10^3yr	10^4yr
Oldsmar E. Eocene	Shallow Marine Bank	0.077	0.77	1.5	9.6	1%	13%	26%	100%
Eocene Total		0.22	2.2	4.3	27	1%	13%	25%	100%
Cedar Key Paleocene	Shallow Marine Bank	0.13	1.3	2.7	16	1%	13%	27%	100%

[1] See text for sources.

[2] Computed from the following rates of deposition (in mm/10^3 yr), from Schindel (1980) and Sadler (1981):

Environment	Span of observation			
	10^0yr	10^2yr	10^3yr	10^4yr
Shallow carbonates	10,000	1,000	500	80
Fluvial	90,000	6,000	1,000	700
Deltaic-Coastal Wetlands	500,000	10,000	5,000	800

[3] Columns do not total correctly because of rounding off of values.

mation to be mainly fluvial in origin (Puri and Vernon, 1964; Williams et al., 1977; Webb et al., 1981). Both of these environmental assignments are probably oversimplifications when the complexity of these units is considered. However, in my view, they are the best approximations possible for this approach.

The calculated amount of time represented in peninsular Florida by the major Cenozoic strata is shown in the central columns of Table 2. The columns list estimates based on 1, 100, 1,000, and 10,000 yr levels of resolution. These data indicate that at the 1 yr level of resolution very little time is represented by any of the strata. The highest value is 220,000 yr which is for the entire Eocene rock sequence. The values become larger with longer periods of resolution. By the 10,000 yr level of resolution, the strata often have values of millions of years, indicating how much time they represent if we permit temporal gaps of 10,000 yr. The Paleocene and essentially both of the Middle Eocene units probably represent 1 million yr or more even allowing gaps of only 100 yr, indicating that during those times, peninsular Florida was undergoing shorter periods of erosion/non-deposition than during later times. The single unit which of itself seems to represent the most time (at all levels of resolution) is the Cedar Key Formation which includes all of the Paleocene rock in the record.

The completeness of the strata is shown in the right hand column of Table 2. The estimates shown were made by making the time span of each formation equivalent to the duration of the age or epoch to which it is assigned (Table 1). This effectively means that their completeness is equal to the percent of the chronstratigraphic unit which they represent. At a resolution of 1 yr, the completeness of the strata is very low. No single formation represents more than 1% of the time unit to which it belongs and many have rounded values of 0%. Only the Middle Eocene units together make up 2%, the highest value for any age or epoch. All 3 Late Eocene units together represent 1% of that age, individually making up less than 0.5% each. The units later than this, the Oligocene and Miocene strata, represent essentially none of their epochs at this level of resolution. At coarser levels of resolutions, the pattern stays basically the same although of course the values become larger. In the best represented time unit, the Middle Eocene, I estimate that about 20% of the 100 yr intervals are recorded. The formations which seem to singly represent the greatest proportion of their assigned time unit are the Cedar Key Formation (Paleocene) and the Oldsmar Formation (Early Eocene) with completeness of 13% each. The Late Eocene, even though it contains 3 units, has only about a 5% representation while the Oligocene has only 3%. The Miocene strata probably record less than 1 100-yr interval in 200 for a completeness of 0%. At the 1,000 yr level of resolution the Middle Eocene has a 41% representation, while the Paleocene and Early Eocene again follow, with 27% and 26%, respectively. The Late Eocene (11%) and Oligocene (5%) are rather still rather low, as is the Miocene (0%). At the coarsest level of resolution, 10,000 yr, Paleocene, Early Eocene, and Middle

Eocene time all have a representation of 100% as does the whole Eocene. The Late Eocene (69%), Oligocene (20%), and Miocene (4%) all show progressively less representation than those before.

The data shown here support the notion that the Late Eocene sequence of peninsular Florida is quite possibly "oversplit" relative to the Paleocene, Early Eocene, and Middle Eocene sequences. That is, all 3 formations constituting the Late Eocene deposition in the area represent only 4.0 million yr and 69% of the Late Eocene at the 10,000 yr level of resolution. In contrast, each Middle Eocene formation represents significantly more time than all 3 of the Late Eocene formations combined while the sole Early Eocene and Paleocene formations each represent over twice as much time as the three combined. Because the oldest formation to outcrop in Florida is the Middle Eocene Avon Park (Puri and Vernon, 1964), it would appear that the earlier units, which each cover a much longer period of time than those of the surficially exposed Late Eocene, could well be broken down into finer and more numerous units given greater study and accessibility. This is not to say that finer lithostratigraphic divisions would be justified. The Florida carbonate record is probably most practically subdivided by biostratigraphic criteria and nomenclature (McKinney and Jones in press). These would hopefully be applied.

Conclusions—There is a progressive decrease in the amount of time represented by the Cenozoic strata of peninsular Florida as they become younger. Plio-Pleistocene units, though not analyzed here, probably represent relatively little of those times. Even allowing for gaps of 10,000 yr, the Miocene Hawthorne and Alachua Formations together probably represent only about 4% of that epoch. In contrast to the Neogene units, the Paleogene units represent much more time, especially the older ones. Thus, of all the 10,000 yr intervals composing the approximately 22 million yr (LaBrecque et al., 1977) of Neogene time, only about 3% left a sedimentary record, while 100% of those composing the approximately 43 million yr of the Paleogene probably did so. This decreasing completeness as the record becomes younger can be attributed to the general drop in global sea level which has occurred throughout the Cenozoic (Hallam 1977; Vail et al., 1977). This resulted in Florida's emergence from the sea in the early Neogene and the less-complete deposition characteristic of terrestrial environments.

Since a statigraphic completeness of 100% is shown for those units older than Late Eocene age at a resolution of 10,000 yr, it is likely that long-term geologic and biologic processes (e.g., large-scale changes in sedimentary patterns, mass extinctions, ecological replacements) can be observed in these strata. Unfortunately none of these strata are fully exposed in outcrop so any studies of these most-promising units must be based on subsurface samples. As poor as the outlook is for stratigraphic sampling of long-term processes in peninsular Florida (after all, the accessible strata are not really suitable and the suitable strata are not really accessible), the outlook for the study of short-term processes is even poorer. None of the strata are shown to be even near 100% completeness at the 1, 100, or 1,000 yr level of resolution. Even the most complete strata, those before the Late Eocene, have significantly less than 50% completeness at the 1,000 yr level of resolution. Very short term processes, which would require sediment deposition every 1 or 100 yr to observe would be even more difficult to analyze since at best less than 20% of such intervals probably witnessed deposition. This is not to categorically state that such studies cannot or should not be undertaken, only that, if attempted, they should be done with an awareness of the constraints imposed by the completeness and resolution available in the record.

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A SURVEY OF SODIUM AND CHLORIDE CONCENTRATIONS IN FLORIDA LAKES

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Abstract: *A survey of 165 lakes located in different geologic and physiographic regions was conducted to determine sodium and chloride concentrations. Sodium concentrations in the lakes ranged from 1.2 to 1200 mg/l and chloride concentrations ranged from 1.7 to 2300 mg/l. A general increase in concentrations occurs from northwest to southeast Florida. Highest concentrations are found in the lakes of the middle and lower St. Johns River and in coastal lagoon lakes.*

Sodium and chloride are important water quality parameters. Excessive concentrations can impart a salty taste to drinking water, increase the corrosion of steel and aluminum, limit the usability of irrigation water and harm aquatic life (McKee and Wolf, 1963). Sodium and chloride, however, are found in all natural waters. Runoff from surrounding soils, ground-water, and atmospheric precipitation are the major natural sources of these ions in lakes. Although Florida has over 7,700 lakes (Florida Board of Conservation 1969) and these lakes provide water for many domestic, industrial, agricultural, and recreational activities, there is very little information available on sodium and chloride concentrations in these waters. In this study, I document the general statewide distribution of sodium and chloride concentrations in Florida's lakes.

Methods—Between September 1979 and August 1980, surface water (0.5 m) samples were collected on 3 occasions from 165 lakes located throughout Florida (Table 1). Because the mineral composition of lakes is influenced by geologic and hydrologic factors, the study lakes were selected to provide a representative sample of lakes located in the major physiographic regions (Table 1) described by Puri and Vernon (1964) and White (1970). At each lake, samples were collected at 3 midlake locations. For each sample, chloride concentrations were determined by titration with 0.0141 N mercuric nitrate. Diphenylcarbazone was used for endpoint determination (A.P.H.A., 1976). Sodium concentrations were determined by flame photometry (A.P.H.A., 1976). For sodium and chloride concentrations below 10 mg/l, all measurements were made to the nearest 0.1 mg/l. Above 10 mg/l, all measurements were made to the nearest 1 mg/l. All samples (9) were averaged to provide an estimate of each lake. Estimated values were compared to sodium and chloride data in Florida Game and Fresh Water Fish Commission reports (Holcomb, 1968, 1969; Duchrow, 1970, 1971; Duchrow and Starling, 1972; Holcomb and Starling, 1973).

Results and Discussion—Average sodium and chloride concentrations and the 95% confidence limits for the lakes in my study are in Table 1. A wide range of concentrations was found. Average sodium concentrations ranged from 1.2 mg/l in Carr Lake to 1200 mg/l in Western Lake. Average chloride concentrations ranged from 1.7 mg/l in Charles' Bay to 2300 mg/l in Western Lake. For the sampled lakes, 25% had sodium concentrations below 4.9 mg/l, 50% had sodium levels below 7.6 mg/l, and 75% had

Table 1. Average sodium and chloride concentrations and 95% confidence limits for some Florida lakes between September 1979 and August 1980. Numbers with 1 asterisk are average values for 1967-1973; numbers in parentheses are minimum and maximum values measured (Holcomb, 1968, 1969; Duchrow, 1970, 1971; Duchrow and Starling, 1972; Holcomb and Starling, 1973). Numbers followed by 2 asterisks are average values for 1973-1979 (U.S. Army Corps of Engineers, unpubl. data).

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Lake Agnes	Polk	Winter Haven Ridge	9.5 ± 0.3	20 ± 1
Alligator Lake	Columbia	Northern Highlands	6.6 ± 2.6	8.3 ± 2.4
			10* (4.2-13)	15* (15-15)
Alligator Lake	Osceola	Osceola Plain	11 ± 1	23 ± 1
Lake Apopka	Lake/Orange	Central Valley	19 ± 2	35 ± 1
			13* (11-15)	27* (25-28)
Lake Arbuckle	Polk	Osceola Plain	7.6 ± 0.6	13 ± 1
Ariana Lake	Polk	Winter Haven Ridge	15 ± 0	22 ± 0
Lake Arietta	Polk	Winter Haven Ridge	15 ± 0	27 ± 1
Lake Ashby	Volusia	Eastern Valley	7.2 ± 0.8	14 ± 1.9
Lake Baldwin	Orange	Orlando Ridge	7.6 ± .41	11 ± 0
Bear Lake	Santa Rosa	Western Highlands	2.3 ± 0.2	2.9 ± 0.2
			1.5* (0.9-1.9)	2.7* (2.5-3.0)
Blue Cypress Lake	Indian River	Eastern Valley	19 ± 1	37 ± 3
			21** (15-30)	47** (32-61)
Lake Broward	Putnam	Crescent City Ridge	7.0 ± 0.3	11 ± 0
Lake Buffam	Polk	Polk Upland	9.1 ± .6	17 ± 1
Lake Butler	Orange	Mount Dora Ridge	14 ± 1	27 ± 0
			12* (11-14)	20* (18-22)
Lake Butler	Union	Northern Highlands	4.9 ± .7	7.7 ± .4
			3.3* (2.7-3.7)	3.8* (2.5-4.0)
Carr Lake	Leon	Tallahassee Hills	1.1 ± .7	2.7 ± .2
Charles' Bay (Smith Lake)	Washington	Marianna Lowlands	1.4 ± .1	1.7 ± .2
Cherry Lake	Madison	Tallahassee Hills	4.4 ± .3	6.8 ± .1
Lake Clinch	Polk	Polk Upland	6.9 ± .5	12 ± 0
Compass Lake	Jackson	New Hope Ridge	1.5 ± .3	3.1 ± .1
Lake Conway	Orange	Orlando Ridge	16 ± 1	24 ± 0
Corn Landing Lake	Franklin	Gulf Coastal Lowlands	27 ± 1	44 ± 4
Crescent Lake	Lake	Lake Upland	7.7 ± .4	14 ± 1

TABLE 1. CONTINUED.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Crescent Lake	Flagler/Putnam	Eastern Valley	26 ± 10	52 ± 21
Crews Lake	Pasco	Gulf Coastal Lowlands	5.0 ± .4	10 ± 1
Lake Crosby	Bradford	Northern Highlands	4.7 ± .6	7.0 ± .2
Crystal Lake	Washington	Greenhead Slope	1.7 ± .2	2.1 ± .2
Cypress Lake	Osceola	Osceola Plain	14 ± 1	22 ± 2
Dead Lake	Calhoun/Gulf	Gulf Coastal Lowlands	3.1 ± 1.8	3.2 ± .2
			3.1* (2.0-4.5)	2.8* (1.5-4.0)
Lake Deaton	Sumter	Sumter Upland	20 ± 1	32 ± 1
Deer Point Lake	Bay	Gulf Coastal Lowlands	4.0 ± 2	4.6 ± .4
			4.6* (2.7-7.4)	9.1* (6.0-14)
Lake Dexter	Volusia/Lake	St. Johns River Offset	104 ± 27	190 ± 49
Lake Dias	Volusia	Eastern Valley	7.4 ± .4	13 ± 0
Dinner Lake	Highlands	Lake Wales Ridge	10 ± .8	16 ± .4
Lake Disston	Flagler	Eastern Valley	6.0 ± .6	9.9 ± 1.9
Lake Dora	Lake	Central Valley	17 ± 1	32 ± 1
			15* (12-16)	28* (27-29)
Lake Dorr	Lake	Marion Upland	5.1 ± .4	7.3 ± .3
			4.9 (4.4-5.4)	9.5* (9.5-9.5)
Lake Down	Orange	Mount Dora Ridge	13 ± 1	25 ± a
Dunford Pond	Washington	Greenhead Slope	1.7 ± .1	2.2 ± .2
Eagle Lake	Polk	Winter Haven Ridge	15 ± 1	26 ± 0
Lake Eaton	Marion	Central Valley	5.2 ± .4	8.2 ± .5
Lake Ellen	Wakulla	Gulf Coastal Lowlands	2.6 ± .1	3.5 ± .2
Lake Eustis	Lake	Central Valley	13 ± 0	23 ± 0
			11* (9.8-13)	20* (18-22)
Lake Fairview	Orange	Orlando Ridge	9.6 ± .3	14 ± 1
Gap Pond	Washington	Greenhead Slope	1.7 ± .1	2.1 ± .2
Lake Geneva	Clay	Northern Highlands	6.7 ± .7	8.9 ± .1
			4.3* (4.0-4.8)	7.8* (7.0-8.5)
Lake Gentry	Osceola	Osceola Plain	11 ± 1	21 ± 2
Lake George	Volusia/Putnam	St. Johns River Offset	129 ± 21	233 ± 40
Lake Gibson	Polk	Polk Upland	9.9 ± .7	15 ± .6
			11* (7.7-15)	18* (16-19)

Table 1. Continued.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Lake Griffin	Lake	Central Valley	15 ± 0	24 ± 1
Hampton Lake	Bradford	Northern Highlands	5.7 ± .6	8.6 ± .4
Lake Harney	Seminole/Volusia	Eastern Valley	186 ± 96	327 ± 153
Lake Harris	Lake	Central Valley	9.9 ± .4	17 ± 0
			7.4* (6.0-8.3)	14* (13-15)
Lake Hart	Orange	Osceola Plain	9.3 ± .5	18 ± 1
Lake Hatchineha	Polk/Osceola	Osceola Plain	7.9 ± 1	14 ± 1.5
Lake Howard	Polk	Winter Haven Ridge	12 ± 1	17 ± 0
Lake Huntley	Highlands	Lake Wales Ridge	8.2 ± .5	15 ± 1
Hurricane Lake	Okaloosa	Western Highlands	2.0 ± .2	2.6 ± .2
Lake Iamonia	Leon	Tallahassee Hills	1.6 ± .8	3.2 ± .2
Lake Iola	Pasco	Brooksville Ridge	8.4 ± .3	16 ± 0
Lake Istokpoga	Highlands	Okeechobee Plain	7.7 ± .5	14 ± 1
Lake Jackson	Highlands	Intraridge Valley	7.9 ± .5	14 ± 0
			5.9* (4.9-20)	12* (10-13)
Lake Jackson	Leon	Tallahassee Hills	2.0 ± .6	3.3 ± .1
Lake Jackson	Walton	Western Highlands	1.8 ± .2	2.6 ± .1
			2.1* (1.6-3.2)	2.0* (2.0-2.0)
Lake Jessamine	Orange	Orlando Ridge	14 ± 1	21 ± 0
Lake Jessup	Seminole	St. Johns River Offset	101 ± 23	183 ± 37
Johns Lake	Lake/Orange	Lake Wales Ridge	14 ± 1	30 ± 1
			12* (9.5-16)	25* (24-25)
Lake Josephine	Highlands	Intraridge Valley	6.5 ± .3	11 ± 0
Juniper Bay	Walton	Western Highlands	1.8 ± .1	2.1 ± .1
Karick Lake	Okaloosa	Western Highlands	2.0 ± .2	2.6 ± .3
			1.6* (1.3-1.9)	3.2* (2.8-4.0)
Lake Kerr	Marion	Marion Upland	10 ± 0	17 ± 0
			9.3* (8.3-11)	18* (17-19)
Kingsley Lake	Clay	Trail Ridge	5.0 ± .3	7.0 ± .2
Lake Kissimmee	Osceola	Osceola Plain	10 ± 0	15 ± 2
Lawne Lake	Orange	Osceola Plain	11 ± 1	14 ± 0
Lake Lindsey	Hernando	Brooksville Ridge	5.7 ± .6	11 ± 0
			2.8* (2.3-3.1)	5.8* (4.8-6.5)

Table 1. Continued.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Little Crooked Lake	Polk	Polk Upland	9.1 ± 1.2	16 ± 2
Little Red Water Lake	Highlands	Intraridge Valley	5.0 ± .4	8.7 ± .3
Lochloosa Lake	Alachua	Central Valley	5.6 ± .1	8.8 ± .3
			5.1* (4.1-6.0)	10* (9.0-11)
Lake Lotela	Highlands	Lake Wales Ridge	7.5 ± .4	12 ± 0
Lake Louisa	Lake	Lake Upland	7.1 ± .6	14 ± 1
Lake Louise	Suwannee	Northern Highlands	4.1 ± .4	7.8 ± .3
Lake Lowery	Polk	Polk Upland	13 ± 1	25 ± 1
Lowery Lake	Clay	Trail Ridge	2.7 ± .4	4.3 ± .2
Lake Maggiore	Pinellas	Gulf Coastal Lowlands	134 ± 30	275 ± 51
			174* (60-260)	436* (300-550)
Magnolia Lake	Clay	Trail Ridge	2.5 ± .6	4.4 ± .1
Lake Maitland	Orange	Orlando Ridge	8.8 ± .5	16 ± 1
			10* (8.4-12)	16* (16-17)
Lake Manatee	Manatee	Gulf Coastal Lowlands	6.0 ± .6	12 ± 1
Lake Margaret	Putnam	Crescent City Ridge	7.0 ± .2	10 ± 1
Lake Marian	Osceola	Osceola Plain	8.9 ± .7	16 ± 1
Lake Marion	Polk	Lake Wales Ridge	4.7 ± .2	9.0 ± .5
Lake Mary Jane	Orange	Osceola Plain	9.0 ± .8	17 ± 1
Lake McKenzie	Calhoun	New Hope Ridge	1.7 ± .2	2.0 ± .1
Merial Lake	Bay	Greenhead Slope	2.0 ± .2	2.6 ± .2
Orange Lake	Alachua	Central Valley	6.3 ± .4	8.9 ± .2
			5.1* (4.2-5.8)	9.8* (9.5-10)
Osborne Lake	Palm Beach	Atlantic Coastal Ridge	39 ± 6	58 ± 8
Otter Lake	Wakulla	Gulf Coastal Lowlands	21 ± 17	36 ± 31
Oyster Lake	Walton	Gulf Coastal Lowlands	837 ± 570	1600 ± 1100
Lake Padgett	Pasco	Gulf Coastal Lowlands	9.4 ± .8	17 ± 1
Palestine Lake (South Prong Pond)	Union	Northern Highlands	4.2 ± .6	5.9 ± .2
			2.7* (2.4-3.2)	4.0* (3.5-4.5)
Lake Panasoffkee	Sumter	Tsala Apopka Plain	5.7 ± .5	9.6 ± .5
			5.5* (4.5-9.4)	7.8* (6.5-9.0)
Lake Parker	Polk	Polk Upland	13 ± 1	20 ± 1
Lake Pasadena	Pasco	Brooksville Ridge	7.9 ± .4	20 ± 1

TABLE 1. CONTINUED.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Pate Pond	Washington	Marianna Lowlands	1.9 ± .1	2.5 ± .4
Lake Pierce	Polk	Lake Wales Ridge	5.5 ± .5	10 ± 1
			4.7* (3.7-5.6)	8.3* (7.5-9.0)
Lake Placid	Highlands	Intraridge Valley	5.6 ± .4	10 ± 0
Lake Poinsett	Brevard	Eastern Valley	111 ± 42	227 ± 83
			73** (16-260)	165** (37-585)
Red Beach Lake	Highlands	Lake Wales Ridge	5.6 ± .5	10 ± 1
			4.1* (3.7-4.4)	6.5* (6.0-6.8)
Merritts Mill Pond	Jackson	Marianna Lowlands	1.9 ± .3	3.6 ± .2
Lake Minnehaha	Lake	Lake Upland	7.7 ± .5	14 ± 1
			5.4* (4.5-6.0)	11* (10-11)
Lake Minneola	Lake	Lake Upland	8.6 ± .4	15 ± 1
			5.8* (4.7-6.7)	13* (12-13)
Lake Miona	Sumter	Sumter Upland	11 ± 1	20 ± 0
Mirrow Lake	Calhoun	New Hope Ridge	1.7 ± .3	1.9 ± .1
Lake Monroe	Seminole/Volusia	St. Johns River Offset	140 ± 45	261 ± 94
Moon Lake	Pasco	Gulf Coastal Lowlands	8.9 ± .3	16 ± .3
			6.9* (5.6-8.0)	12* (10-13)
Mountain Lake	Hernando	Brooksville Ridge	5.4 ± .1	9.3 ± .2
Lake Munson	Leon	Lake Munson Hills	16 ± 4	18 ± 5
Mystic Lake	Madison	Tallahassee Hills	2.2 ± .8	4.0 ± .3
Newnans Lake	Alachua	Central Valley	6.3 ± .6	8.7 ± .3
Ocean Pond	Baker	Northern Highlands	4.1 ± .6	6.3 ± .3
			3.2* (2.4-3.9)	5.4* (4.0-7.0)
Ocheesee Pond	Jackson	Grand Ridge	1.6 ± .3	3.0 ± .2
Lake Okahumpka	Sumter	Sumter Upland	13 ± 1	23 ± 1
Lake Okeechobee	Okeechobee/Martin Glades/Palm Beach/ Hendry	Okeechobee Plain	46 ± 1	71 ± 2
Lake Talquin	Gadsden/Leon	Tallahassee Hills	7.0 ± 2	10 ± 3
			5.2* (3.7-7.7)	9.0* (7.0-11)
Lake Tarpon	Pinellas	Gulf Coastal Lowlands	89 ± 8	172 ± 15
			1042* (177-2800)	4400* (3800-5020)

TABLE 1. CONTINUED.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Lake Thonotosassa	Hillsborough	Gulf Coastal Lowlands	22 ± 2	26 ± 2
			11* (7.6-15)	14* (10-17)
Tiger Lake	Polk	Osceola Plain	7.5 ± .4	13 ± 1
Tigertail	Broward	Atlantic Coastal Ridge	16 ± 0	24 ± 0
Lake Tohopekaliga	Osceola	Osceola Plain	18 ± 5	25 ± 4
East Lake Tohopekaliga	Osceola	Osceola Plain	11 ± 1	21 ± 1
Townsend Pond	Lafayette	Gulf Coastal Lowlands	2.6 ± .7	3.4 ± .4
(Koon Lake)			2.4* (1.7-3.7)	5.1* (3.5-6.5)
Lake Trafford	Collier	Immokalee Rise	16 ± 1	27 ± 2
Tsala Apopka Lake	Citrus	Tsala Apopka Plain	5.4 ± .6	8.9 ± .4
(Hernando Pool)			4.3* (3.6-5.3)	7.4* (5.5-8.2)
Turkey Pen Pond	Calhoun	New Hope Ridge	1.7 ± .2	2.0 ± .1
Lake Underhill	Orange	Orlando Ridge	6.5 ± .4	9.8 ± .3
			6.2* (5.5-6.8)	12* (12-13)
Upper Myakka Lake	Sarasota	Gulf Coastal Lowlands	8.8 ± .8	16 ± 1
Lake Victor	Holmes	Marianna Lowlands	1.8 ± .2	2.9 ± .2
Lake Virginia	Orange	Orlando Ridge	8.8 ± .3	16 ± 1
			8.8* (7.8-9.7)	16* (15-18)
Reedy Lake	Polk	Lake Wales Ridge	11 ± 1	16 ± 0
			9.4* (4.4-12)	13* (12-14)
Lake Rosalie	Polk	Osceola Plain	6.9 ± .4	13 ± 0
Round Lake	Jackson	New Hope Ridge	1.9 ± 3	3.2 ± .1
Lake Rousseau	Levy/Marion/ Citrus	Gulf Coastal Lowlands	4.1 ± .7	6.3 ± .6
Lake Rowell	Bradford	Northern Highlands	18 ± 4	9.2 ± .2
Lake Sampson	Bradford	Northern Highlands	12 ± 2	8.3 ± .4
			10* (5.8-17)	6.8 (6.0-7.5)
Santa Fe Lake	Alachua	Northern Highlands	6.8 ± .7	9.7 ± .2
Lake Sebring	Highlands	Intraridge Valley	5.0 ± .3	8.8 ± .4
Sellers Lake	Marion/Lake	Marion Upland	4.6 ± .4	6.6 ± .2
Lake Seminole	Gadsden/Jackson	Marianna Lowlands	5.8 ± 1	3.3 ± .5
Lake Seminole	Pinellas	Gulf Coastal Lowlands	37 ± 3	66 ± 5
			37* (17-37)	106* (92-120)

Table 1. Continued.

Lake	County	Physiographic Region	Sodium (mg/l)	Chloride (mg/l)
Smith Lake	Marion	Sumter Upland	6.5 ± .3	11 ± 0
Lake Stanley	Walton	Western Highlands	2.8 ± .2	3.1 ± .2
Lake Stella	Putnam	Crescent City Ridge	16 ± 0	27 ± 1
Sun Lake	Holmes	Marianna Lowlands	2.0 ± .1	2.8 ± .4
Lake Susan	Lake	Lake Upland	7.2 ± .5	14 ± 1
Suwannee Lake	Suwannee	Northern Highlands	3.0 ± .5	5.7 ± .1
Lake Wales	Polk	Lake Wales Ridge	6.1 ± .4	10 ± 1
			6.6* (5.4-7.0)	12* (10-12)
Lake Washington	Brevard	Eastern Valley	45 ± 1	97 ± 20
			33** (7.0-80)	92** (8.8-416)
Watertown Lake	Columbia	Northern Highlands	6.8 ± .5	8.0 ± .4
			5.3* (2.3-7.6)	8.6* (7.2-10)
Lake Wauberg	Alachua	Central Valley	8.2 ± .6	11 ± 0
Lake Weir	Marion	Sumter Upland	17 ± 1	28 ± 0
Lake Weohyakapka	Polk	Osceola Plain	6.3 ± .3	14 ± 3
Western Lake	Walton	Gulf Coastal Lowlands	1200 ± 600	2600 ± 1000
Wildcat Lake	Lake	Marion Upland	4.4 ± .4	6.5 ± .3
Lake Wimico	Gulf	Gulf Coastal Lowlands	16 ± 12	28 ± 23
Lake Winnemissett	Volusia	Deland Ridge	9.0 ± .8	16 ± 0
Lake Yale	Lake	Central Valley	20 ± 1	23 ± 0
			18* (16-20)	23 (22-24)

sodium concentrations less than 13 mg/l. Chloride concentrations were less than 7.0 mg/l in 25% of the lake. Half the sampled lakes had chloride concentrations less than 13 mg/l and 75% had chloride levels below 21 mg/l. Only 6% of the lakes had sodium or chloride concentrations greater than 100 mg/l thus sodium and chloride levels are not a major water quality problem in most Florida lakes.

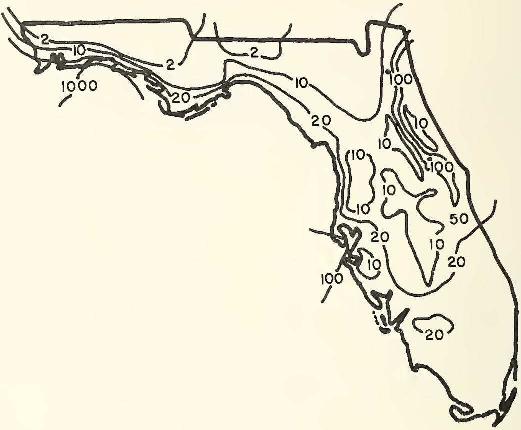

FIG. 1. Distribution of lake sodium concentrations (mg/l) in Florida. Isograms represent maximum values except where ● occurs then isograms represent minimum values.

Although there is considerable variability in lake concentrations, analysis of the data indicates there are distinct regional differences. A general increase in sodium (Fig. 1) and chloride (Fig. 2) concentrations occurs as one moves from northwest to southeast Florida. Lakes located on ridges such as the Mount Dora Ridge, the Deland Ridge, and the Lake Wales Ridge generally have lower concentrations than lakes located in the surrounding lowlands. Lakes of the middle and lower St. Johns River have high concentrations because of inputs of mineralized water derived from marine sediments and salt springs (McLane, 1955; Kaufman, 1975). Coastal lakes, especially coastal lagoon lakes like Western Lake have higher concentrations than inland lakes because of salt water intrusion.

With a few exceptions (cf. Lake Tarpon), there is good agreement between my reported sodium and chloride concentrations and long-term (1967-1973) values reported by the Florida Game and Fresh Water Fish Commission (Table 1). I, therefore, conclude the statewide distribution of sodium and chloride concentrations in lakes is largely determined by

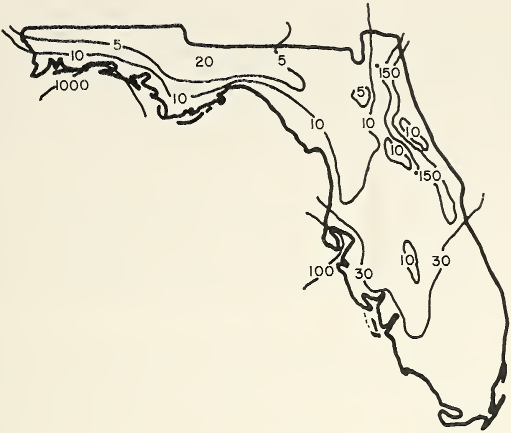

Fig. 2. Distribution of lake chloride concentrations (mg/l) in Florida. Isograms represent maximum values except where ● occurs then isograms represent minimum values.

regional geology. Although edaphic factors establish a general regional potential, anthropogenic activities and hydrologic factors can modify conditions. For example, in 1969 the Southwest Florida Water Management District constructed a dike around a sinkhole which was discharging saline water into Lake Tarpon (Hunn, 1974). Since enclosure of the sink, Lake Tarpon has become less saline (Hunn 1974; Table 1). Western Lake had average sodium and chloride concentrations of 2100 and 4000 mg/l respectively, in January 1980. After heavy summer rains, August sodium and chloride concentrations average 900 and 1700 mg/1 respectively. Similar large variations in salinity are also found in lakes of the St. Johns River (Table 1). Because large seasonal and annual variations characterize Florida rainfall (Bradley, 1975), significant variations in lake sodium and chloride concentrations will occur within a region, but the general pattern of regional differences documented in this paper should remain relatively constant. As more data become available, a more definitive delineation of regional differences will be possible.

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AREAL RAINFALL VARIABILITY AND THE DESIGN OF A RAINFALL MONITORING NETWORK FOR SHARK RIVER SLOUGH, EVERGLADES NATIONAL PARK, FLORIDA

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ABSTRACT: *Biweekly rainfall was measured from an 87-station rainfall monitoring network located in Shark River Slough for 22 mo beginning in December 1977. Mean cumulative rainfall (201.7 cm) was 24% less than that calculated from 3 NOAA stations monitored daily at the periphery of the slough. Areal variability of precipitation within the slough ranges from 150 cm in the northeast area to more than 230 cm in southern area. Information gained on rainfall was used to design an efficient and accurate long-term rainfall network for this 1000 km² area.*

SHARK RIVER SLOUGH is located at the southern end of the Kissimmee-Okeechobee-Everglades drainage system in southern Florida. The slough provides critical habitat for plant and animal communities intricately dependent upon fluctuating water levels. Its waters help recharge the Biscayne Aquifer, which is the drinking water supply for southeastern Florida, and its freshwater outflows moderate salinities of downstream estuarine regions. Rainfall in the slough is seasonal, with more than 80% of the annual precipitation occurring during the 6 mo wet season lasting from May through October (Lew et al., 1982). During this time, localized convective showers and thunderstorms predominate, producing considerable variability in rainfall amounts over a relatively small area. Because of this variability, and water management needs for an accurate quantification of precipitation, an 87 station rainfall monitoring network was maintained in the slough from December 1977 through September 1979.

Our study area was approximately the 1000 km² portion of the Shark River Slough which lies south of U.S. Highway 41 (Fig. 1). Nearly 80% of the region lies within the confines of Everglades National Park. The remaining 20% lies east of the park boundary in a region known as northeast Shark Slough. The 2 major sources of water to the slough are direct rainfall and surface water inflows, the latter being routinely measured as part of a joint program between the National Park Service, U.S. Army Corps of Engineers and the U.S. Geological Survey.

We were to assess the geographic variability of rainfall occurring in the southern Everglades and in doing so, design a long-term precipitation monitoring network that would allow an accurate estimate of total rainfall in an area noted for its rainfall variability.

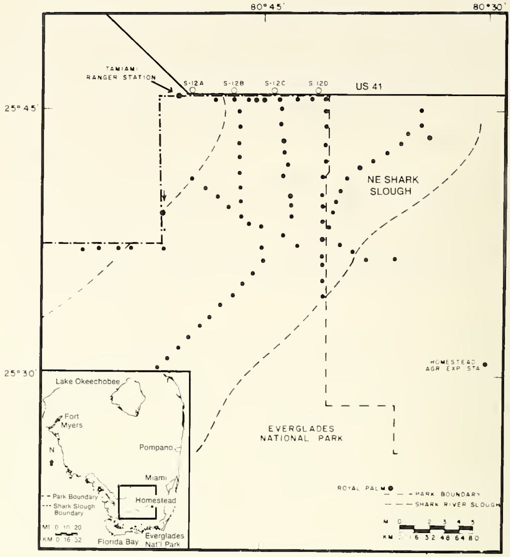

FIG. 1. Map of the rain gauge network for the Shark River Slough, Everglades National Park, Florida.

METHODOLOGY—Biweekly rainfall inputs to the slough was obtained at 87 sites utilizing 15.2 cm capacity, plastic wedge-type gauges, within which mineral oil was placed as an evaporation suppressant.

The Thiessen-weighted averaging technique is used for estimating areal rainfall from the point sources of data. In this method, each rain gauge is assigned a weighting factor based on the area of its corresponding polygon. The polygons are delineated by the perpendicular bisectors between each gauge and its closest neighbor, in conjunction with watershed boundaries (Dunne and Leopold, 1978). In addition, an isohyetal map of the 22 mo cumulative rainfall was constructed to portray areal variability in precipitation patterns.

Four sets of Thiessen polygons were constructed, consisting of 87, 29, 11 and 3 gauge networks (Fig. 2), from which appropriate weighting factors reflecting polygon areas were determined. Mean basin rainfall estimates for each of the biweekly monitoring intervals based on data collected from the 87 wedge-gauges are compared with estimates based on the 29, 11 and 3 gauge subnetworks to determine the loss of accuracy resulting from reduction in network size. The 87 gauge network was used as the standard against which the subnetworks were judged. The absolute error occurring throughout the study was obtained by calculating the absolute value of the difference between the full 87 gauge network cumulative rainfall amounts, and each of the subnetworks. Mean biweekly error and standard deviation were also calculated for each subnetwork.

Finally, based upon assessment of the total and biweekly error determined among the subnetworks and geographical variability apparent in the isohyetal analysis, an efficient and accurate rainfall monitoring network has been designed.

RESULTS AND DISCUSSION—An analysis of the 87 gauge rainfall network shows that the 22 mo cumulative rainfall (December 1977-September 1979) was 201.7 cm and ranged from 150 cm in northeastern Shark Slough to more than 230 cm in southern Shark Slough (Fig. 3).

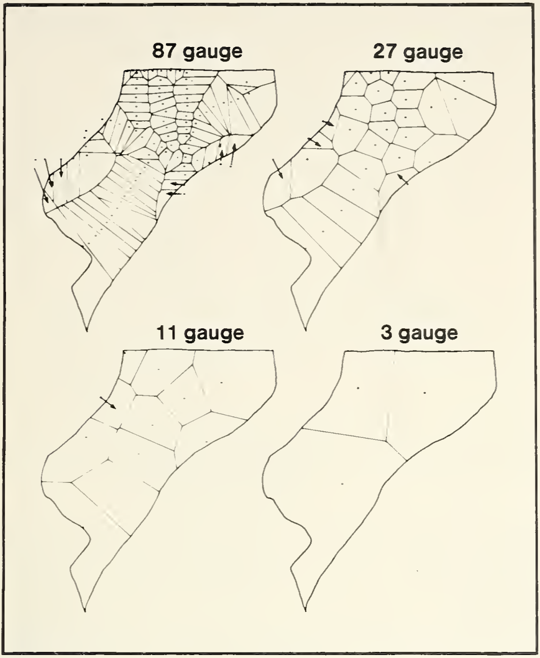

FIG. 2. Thiessen polygon representation of the 87, 29, 11 and 3 rain gauge subnetworks.

Previous studies concerning the problems of network design have shown that evenly distributed, symmetrically placed gauges increase network accuracy (Kelway, 1974). Optimal design, however, is also a function of practical considerations such as available manpower, accessibility, and minimization of ecosystem disturbance. The gauges in the Shark River Slough monitoring network were placed at regular 1.6 km intervals along existing airboat trails. The 29, 11 and 3 gauge subnetworks were chosen to approximate the spatial configuration of the 87 gauge network. Among these networks, accuracy increased as density increased.

The 87 gauge network had a mean density of 11.4 km^2/gauge, and a density range of 1.04 km^2/gauge to 69.6 km^2/gauge. This compares favorably with previously reported criteria of the 65 km^2/gauge, allowing for the detection of 90% of all showers when mean area rainfall was between 0.025 cm and 0.13 cm; and 570 km^2/gauge, allowing for detection of all rain days when mean area rainfall was greater than 1.3 cm (Woodley et al., 1975). A comparison of subnetwork error (Table 1) showed that error increased as gauge number and density decreased, reaching a maximum error for

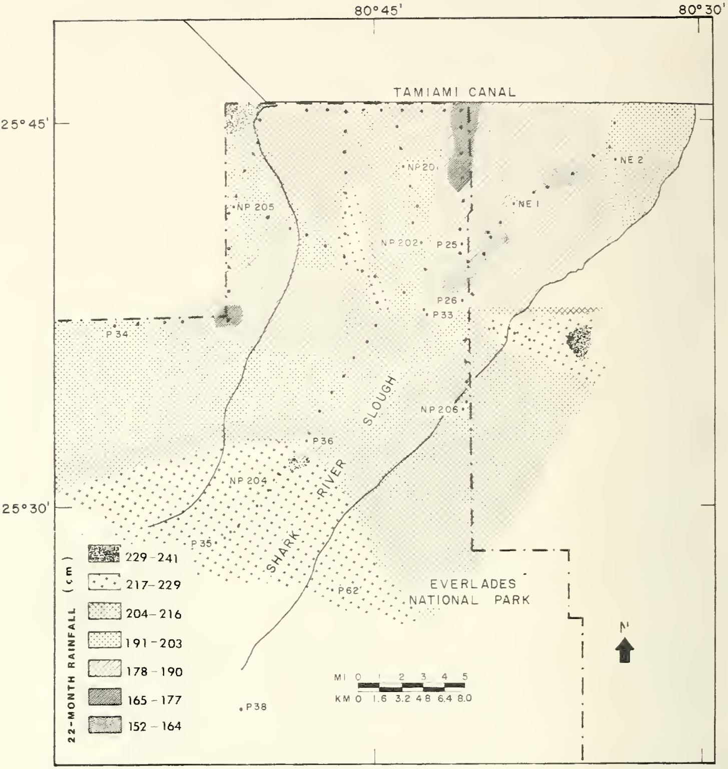

FIG. 3. Isohyetal distribution of cumulative rainfall into Shark Slough, December 1977-September 1979.

cumulative 22 mo rainfall of 6.5 cm (3.2%) for the 3 gauge subnetwork estimate. This cumulative rainfall error is much less than would have been calculated by multiplying mean biweekly absolute error by the number of monitoring intervals. This reflects cancellation of deviations occurring when interval estimates were summed.

Variations of rainfall measurements at contiguous individual locations often varied as much as 5% during a single biweekly interval and occasionally as much as 30% (Lew et al., 1982). Most of this variability is attributed to the localized nature of convective rainfall events, but on several occasions may be related to inadequate exposure of individual gauges in storms having intense winds.

TABLE 1. A comparison of the Shark River Slough rain gauge network during 1 December 1977-20 September 1979.

	87 Gauge Full Network	29 Gauge Sub-network	11 Gauge Sub-network	3 Gauge Sub-network	3 Weather Stations
Mean Gauge Density (km²/gauge)	11.4	34.2	90.1	331.0	331.0
Cumulative Rainfall (cm)	201.8	200.6	197.6	208.1	263.9
*Absolute Error (cm)	0.0	1.1	4.4	6.40	62.1
**Mean Biweekly Error (cm)	0.0	0.2	0.4	0.7	-

*Absolute error = $N_{87} - N_S$,
where N_{87} = estimate of cumulative rainfall based on 87 gauge network,
N_S = estimate of cumulative rainfall based on subnetwork S,
and S = 29, 11, or 3 gauge subnetwork.

$$\text{**Mean biweekly error} = \frac{\sum_{i=1}^{n} |I_{87} - I_S|}{n},$$

where n = number of monitoring intervals = 46,
I_{87} = estimate of monitoring interval rainfall based on 87 gauge network,
I_S = estimate of monitoring interval rainfall based on subnetwork S,
and S = 29, 11, or 3 gauge subnetwork.

In comparing calculated errors among subnetworks from the standpoint of network design, the mean biweekly error is of as much significance as is the annual cumulative error. It is found that reduction from a 29 gauge network to an 11 gauge network increases mean biweekly error by 0.2 cm. A further reduction from an 11 gauge network to a 3 gauge network increases mean biweekly error by an additional 0.4 cm.

The decrease in accuracy as network size is reduced can be compared among subnetworks by determining the percent of intervals in which biweekly error exceeded a specific magnitude. Figure 4 shows that for both the 29 gauge and 11 gauge subnetworks, mean biweekly error exceeded 1.02 cm only 8% of the time. In contrast, mean biweekly error exceeded 1.02 cm 28% of the time in the 3 gauge subnetwork.

The 22 mo cumulative rainfall for the 87 gauge biweekly network (201 cm) is 24% less than the rainfall calculated for the study area based upon daily rainfall measurements (263.9 cm) taken at 3 NOAA stations (Tamiami R.S., Royal Palm R.S. and Homestead Experimental Station) located on the periphery of Shark Slough. Rainfall collected at the 3 weather stations which use standard U.S. Weather Service (USWS) gauges with funnel-shaped openings can be expected to have less deficit catch than the wedge gauges in the 87 gauge network. The funnel design of the USWS gauges reduces loss of catch due to wind effects relative to other elevated gauges (Rodda, 1970). The funnel design, tapering to a 1.5 cm opening, can also be expected to minimize error due to splash out when compared to the wedge gauges with their 36 cm² opening. Further, the smaller, 15.2 cm volume capacity of the

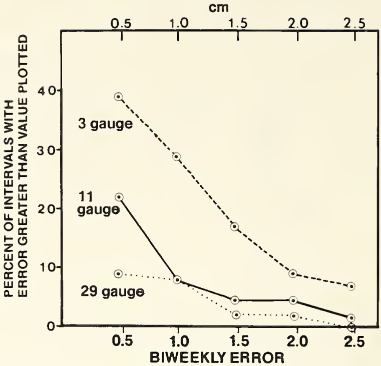

FIG. 4. Duration curve of biweekly rainfall deviation from 87 gauge network for 3, 11 and 29 gauge networks.

wedge gauges, as well as their biweekly monitoring schedule, made these gauges subject to splashout errors which did not occur with the better designed USWS gauges.

Loss of rainfall catch due to wind effects, overflow, and splashout can be reduced by using gauges with funnel-shaped openings and a 61 cm volume capacity. These gauges are more suitable for 3-4 wk accumulations of the heavy wet-season rainfall typical of this region's subtropical climate.

Relying on data from the 3 weather stations peripheral to the slough is not desirable, especially for relatively short time intervals, owing to both the areal variability of precipitation and the doubling of mean biweekly error found when subnetwork size was reduced from 11 to 3 gauges. The optimal network is one closer in size to the 11 gauge network, utilizing the most symmetrical, evenly-distributed sites feasible, given practical considerations. Based upon the areal variability of precipitation patterns, gauge density and design criteria evaluated in this study, a long-term rainfall monitoring network consisting of 8 permanent stations has been developed for the Shark River Slough (Fig. 5). This network is symmetrically spaced and consists of standard U.S. Weather Service 61 cm gauges. The combined advantages of this type of gauge and a network whose mean density is only 124 km^2/gauge will provide an accurate assessment of the rainfall contribution to the Shark River Slough.

CONCLUSIONS—This analysis yields areal estimates of direct rainfall into the 1000 km^2 Shark River Slough during a 22 mo period in 1977-1979 based on biweekly monitoring of a dense 87-gauge network. These estimates were compared to estimates based upon 3 less dense subnetworks, as well as to estimates based upon 3 weather stations where rainfall was monitored daily using distinctly different rain gauges. These comparisons and the suggestions they generated for optimizing future rainfall monitoring networks are as

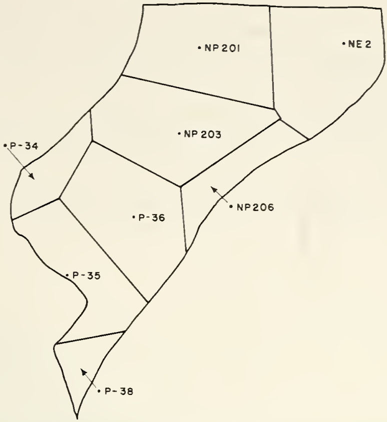

FIG. 5. Thiessen polygon representation of proposed long-term rainfall network design for Shark Slough.

follows: 1) Cumulative mean basin rainfall during December 1977 to 20 September 1979 based upon the most dense 87 gauge network, totalled 201 cm and showed considerable spatial variability ranging from approximately 150 cm to more than 230 cm at different gauge locations within Shark Slough. 2) The 3 subnetworks, consisting of 29, 11 and 3 gauges, had mean biweekly errors of 0.2 cm, 0.36 cm and 0.74 cm respectively, using the 87 gauge network as the standard or "true" rainfall. 3) Subnetwork error for cumulative 22 mo rainfall (December 1977 to 20 September 1979) for the 29, 11 and 3 gauge subnetworks was 1.07 cm (0.5%) 4.19 cm (2%) and 6.40 cm (3.5%) respectively. 4) The estimate of cumulative 22 mo rainfall based upon the 3 weather stations totalled 61.9 cm more than the estimate based upon the 87 gauge network. This difference is explained largely by the fact that the design and low volume capacity of the wedge gauges used in the 87 gauge network, coupled with extended monitoring intervals, makes these gauges poorly suited for this region of heavy wet season rainfall. The wedge gauges are subject to loss of rainfall catch due to overflow, splashout, and wind effects. 5) Loss of rainfall catch can be minimized in future monitoring networks by using standard U.S. Weather Service gauges having a 61 cm volume capacity and a 20.3 cm dia funnel-shaped opening. 6) Optimal network design in the Shark River Slough is the most symmetrical, evenly-distributed configuration of gauges feasible, while minimizing disturbance to the system.

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A BLACKNOSE SHARK FROM NORTH CAROLINA DEFORMED BY ENCIRCLING MONOFILAMENT LINE—

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Abstract: *A deformed female blacknose shark (*Carcharhinus acronotus*) was caught on longline in North Carolina exhibiting an encirclement at the level of the fourth gill slit. Subsequent examination revealed the encirclement to be a continuous monofilament line that had apparently been sewn into the shark rather than a remnant of gill net enmeshing.*

Many marine fishes have been captured which were deformed or possessed foreign items, such as rubber or plastic bands, around various parts of their body (Dawson, 1964, 1966, 1971; Dawson and Heal, 1976; Schwartz, 1963). Ironically, sharks, which are known to have all sorts of incongruous material in their stomachs (Gudger, 1922) or imbedded in their mouths, are rarely captured with external foreign objects on or around their bodies. Spiny dogfish (*Squalus acanthias*) have been found in Scotland (Lamont, 1961) and Norway (Berland, 1971; Hagnestad, 1970) with external man-made artifacts of remnants of cuffs of rubber gloves around their bodies or "through and athwarth its mouth" (Lamont, 1961). Bird (1978) captured tiger sharks (*Galeocerdo cuvieri*), bull sharks (*Carcharhinus leucas*), and dusky sharks (*Carcharhinus obscurus*) (Overstreet, 1978) with packing straps encircling the body anterior to the dorsal fin.

A female blacknose shark (*Carcharhinus acronotus*) 1193 mm TL, 965 mm FL, and 9.9 kg (UNC 16073), was captured 8 July 1980 while longlining in the Atlantic Ocean 2.4 km south of Shackleford Banks, Carteret County, North Carolina. All aspects of the shark's body shape and proportions seemed normal and it was devoid of embryos; however, the skin of the head (142 mm wide x 146 mm high), at the level of the fourth gill slit, was pierced by a seemingly continuous heavy (0.85 mm dia) monofilament line (Fig. 1). Originally, 1 hypothesis was that the shark had been enmeshed in a gill net and the encirclement was the remains of the net that had grown into the shark. Another was that it had been sewn into the shark as a means to mark the shark.

Dissection and X-ray examination of the head revealed that the monofilament was continuous around the head with only one 5.7 mm sheet bend knot protruding from a 7.0 mm hole in the ventral surface of the head. Initially, the monofilament emerged from the head 35.6 mm above the fourth left gill slit, was exposed for 56.5 mm before it passed under the skin and across the top of the head for 35.5 mm. The monofilament lay just under the dorsal body skin and somehow pulled the skin downward to produce a groove 1.95 mm deep. The line resurfaced on the right side of the head to pass 54.3 mm across the skin until it reentered the body 28.1 mm above the fourth right gill slit. The monofilament passed under the skin laterally and ventrally on both left and right sides anterior to the cleithrum of the pectoral fins to unite at the common knot ventrally. Depth of constriction within the body and musculature was 18.6 mm on the left and 20.5 mm on the right side. No regeneration, pulling in or cuts were evident on the skin anywhere along the encirclement. The skin, where the monofilament entered or

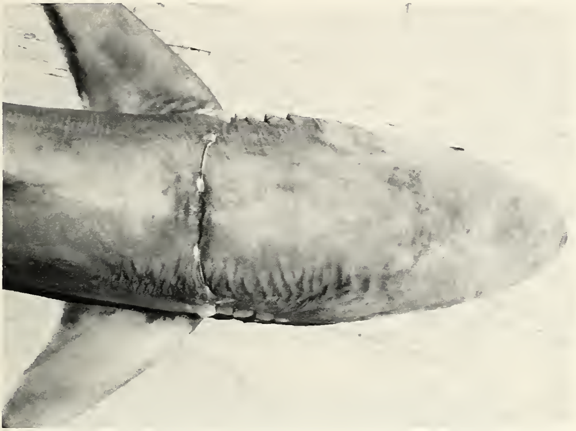

FIG. 1. Female blacknose shark, *Carcharhinus acronotus*, exhibiting encircling monofilament line about head.

pierced the skin, was devoid of denticles and the area around each hole was white. With body growth the monofilament could have penetrated the body of the 4-yr old shark and possibly affected the shark's ability to feed. Age analysis followed Schwartz and Avent (1981). It still remains a mystery how the filament was attached or who would take the time to so mark the shark. Thus even sharks, often considered immune lords of the sea, are increasingly being subjected to the ravages of man's pollution.

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COLOR AND TERATOLOGICAL ABNORMALITIES OF GREEN TURTLE, *CHELONIA MYDAS*, HATCHLINGS FROM NORTH CAROLINA

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Abstract: *A white and several abnormal green turtle hatchlings,* Chelonia mydas, *are reported from the first recorded nesting, in 1980, of the species in North Carolina and north of Georgia.*

During the summer of 1980, the first recorded nesting of a mature female green turtle, *Chelonia mydas*, occurred 5 times on Onslow Beach, Camp Lejeune, Onslow County, North Carolina coast (Schwartz et al., 1981). A total of 819 eggs was deposited as follows: 25 June, 168; 8 July, 183; 21 July, 166; 2 August, 157; 17 August, 145. The first 2 nests were relocated but incubated on Onslow Beach and produced 295 hatchlings 58 da later. The last 3 nests were artificially incubated at 82°F (27.7°C) at the Institute of Marine Sciences, Morehead City, North Carolina, about 48 km northeast of Onslow Beach and yielded a total of 95 hatchlings within 49-59 da.

At birth, one of the 25 June nest hatchlings was completely white, yet black-eyed (Fig. 1). Its straightline carapace length (CL) was 50.5 mm and weight 26.8 g. Note (Fig. 1) that each carapacal scute was outlined in black.

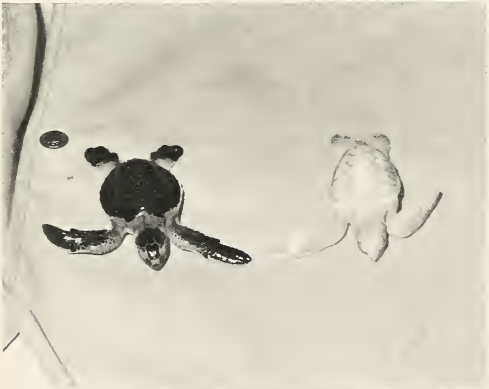

Fig. 1. Normal (left) and white (right) hatchling green turtles from Camp Lejeune, North Carolina.

The specimen lived only 1 da and was preserved. The white hatchling appeared normal, in size and weight, in relation to other hatchlings from the same nest which averaged 50.8 mm CL (47.6-53.8 mm CL range) and 25.8 g (22.8-29.9 g range).

Four teratological specimens also hatched from 2 of the 3 artificially incubated nests (1 specimen from 25 June; 3 from 8 July). The 25 June hatchling measured 48.4 mm CL and weighed 24.7 g. Its right marginals 2 and 3, costal 1, and part of vertebral scute 2 were colored white instead of black. Marginal scute 1 was missing and replaced by skin and 6 small skin pads from the right flipper. An area for half the posterior length of the prefrontal bones suture was undeveloped and covered by white colored skin. The hatchling was normal in all other body features.

One of the 8 July hatchlings (52.8 mm CL, 27.0 g) possessed deformed left marginals 2-4. Costal 1 scute as well as vertebral 2 was divided into 2. The entire area was colored white, including parts of vertebral scutes 2 and 5. Fleshy pads and skin replaced the marginal 1 scute. Ventrally, right plastron scutes 1 and 5, as well as left plastron scute 5, were conspicuously humped. All remaining features of color and scute configuration were normal.

A second 8 July specimen (52.2 mm CL, 27.2 g) exhibited an abnormally arched upper jaw that lacked the characteristic beak or hook of the premaxillae and maxillae. This caused a gap between the upper and lower jaws when closed and through which feeding would have been difficult. All other features were typical *Chelonia*.

The third 8 July deformity (47.3 mm CL, 25.3 g) had both marginal 12 scutes bent upward and forward. The tail was also bent dorsally at an 90° angle. This deflection prevented any horizontal movement of the tail. Color and all other body features were normal. All deformed and normal hatchlings, except the white one, were released into the sea at Onslow Beach within 24 hr of hatching.

Discussion—While albino green (Robinson, 1974; Fletemeyer, 1977) or partially albino loggerheads (Baldwin and Lofton, 1959; Hughes et al., 1967; Harrisson, 1963; Pond, 1972; Rudloe, 1979) are known from scattered geographic localities, the frequency, as in North Carolina, of white individuals within a nest or population remains a rarity. It would be to a sea turtle's advantage to be white, like most silvery fishes, if they were always viewed underwater from below and against the sky, as the white coloration would make them inconspicuous. A white coloration would contrast remarkably with the habitat and render the turtle vulnerable to predation. We can only speculate on the production of white coloration in sea turtles until more is known about their genetics and physiology. Only then will comments on whether the production of a white individual is the result of environmentally induced defects in pigmentation (Ewert, 1979) or is the result of structural gene mutation at the locus coding for tyrosinase (Pawelek and Korner, 1982).

Likewise, teratology in sea turtles has been described as long ago as 1857 by Agassiz and 1899 by Gadow. Early debate centered on whether scute abnormalities were reflections of former atavisms (phylogenetic ancestry) (Gadow, 1899) or teratologies (Coker, 1910; Gadow, 1899, 1905; Grant, 1937; Newman, 1906; Parker, 1901). Subsequently, Zangerl and Johnson (1957), Zangerl (1969), and Ewert (1979) noted that scute abnormalities reflected both genetic and teratological conditions. Temperatures, during development, acute oxygen deficient atmospheres causing abnormal lactic acid development, or effects of barometric pressure changes (Grabowski, 1970) may produce teratological specimens (Ewert, 1979). Perhaps even the amounts of interstitial soil moisture (Bustard and Greenham, 1968) may have indirectly influenced the production of the abnormalities noted herein by altering the available egg oxygen content necessary for development, for Schwartz (1982), in *Caretta*, now correlates percent hatch with nest sand grain size and this indirectly with soil moisture. Sand grain analyses (Folk, 1974) of the artificially incubated nests revealed that they were lain in sands considered optimum by Schwartz (1982), yet the percent hatch varied from nearly 0 to 43%. What caused the decrease in hatchability of the artificially incubated eggs remains unresolved. Only continual investigation will reveal the factor(s) controlling or causing color aberrations or teratology in sea turtles.

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Biological Sciences

RESUMÉ OF THE FLORIDA TAXA OF *CEREUS* (CACTACEAE)

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Abstract: *Populations of native* Cereus *were studied over a 4-yr period, and all were found to be declining. Taxonomic confusion and different concepts of taxa are discussed and conclusions drawn.*

Over the past several years I have studied the native taxa within *Cereus* in Florida. Because there are several populations of *Cereus* that are candidates for either endangered or threatened status pursuant to the Endangered Species Act of 1973, it has been suggested that I make my conclusions available. My ideas are based largely on living plants. Because I have had an opportunity to study living and herbarium material, my conclusions are somewhat different from those of Dr. Lyman Benson, who has generously shared the data that form the basis of his treatment in his upcoming book (Benson, in press).

First, while making it clear that there are wide differences in the forms treated, I have arbitrarily elected to use the genus *Cereus* for all. This stand may be contested by those more familiar with variation in the family; I am not acquainted with enough of the family to make a decision on generic segregates.

1. *Cereus eriophorus* var. *fragrans* (Small) L. Benson, Cactus & Succulent Jour. 41: 126. 1969.

Harrisia fragrans Small, Addisonia 17: 29, 30. pl. 559. 1922. Type: Florida. St. Lucie Co. 20 Dec. 1917. *J.K. Small* (holotype NY; isotypes GH, US).

Virtually all past literature has considered any specimen of *Cereus* growing along Florida's eastern coast to be this taxon. With the exception of a now extirpated stand near Malabar, the variety is currently limited to the type locality. Reports of the variety from Brevard and Volusia counties (Norman, 1976; Poppleton and Shuey, 1977) actually dealt with *Cereus gracilis*. Small himself (Small, 1929) misunderstood the limits of these taxa, and assigned plants in Dade County and elsewhere to his *Harrisia fragrans*. All specimens, except those from the type location of var. *fragrans*, that we have seen in herbaria and growing wild have been *C. gracilis* (Austin et al., 1980).

A major contributor to the confusion seems to have been the lack of understanding that *C. gracilis* is not limited to the Florida Keys and southwestern coast. *Cereus gracilis* also occurs naturally on the eastern coast of Florida. Plants have been found in several sites from Dade County north to Volusia County.

We have seen *C. eriophorus* var. *fragrans* only within a mile to 2-mi strip in St. Lucie County, and that site has been drastically reduced since our last report (Austin et al., 1980). A house now sits on the major population of our 1980 report, although we have found several scattered populations north of that partly extirpated site.

Differences between *C. eriophorus* var. *fragrans* and *C. gracilis* are subtle, but spine length and fruit shape seem to be the most reliable indices (Figs. 1-4).

2. *Cereus gracilis* var. *aboriginum* (Small) L. Benson, Cactus & Succulent Jour. 41: 126. 1969.

Harrisia aboriginum Small in Britton and Rose, The Cactaceae 2: 154. 1920. Type: Florida. Manatee Co. Terra Ceia Island. 29 Apr. 1929. *Small, Cuthbert and DeWinkler* (lectotype NY; isolectotypes US).

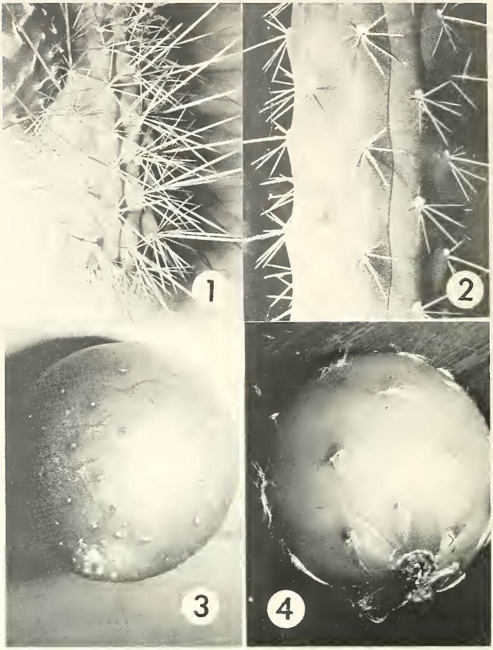
This variety is weakly separated from var. *simpsonii*, and has all but disappeared from areas where it was formerly known. The plants were extirpated from the type locality on Terra Ceia almost a decade ago. At present there are several dispersed populations; all but 1 are found on private land. All other sites have populations that are declining rapidly. Not only have the plants been removed by urbanization, but also there is disease that attacks them and reduces the stems to dead slush within about a week. Perhaps this disease is bacterial, but to my knowledge it has not been studied.

Both var. *aboriginum* and var. *simpsonii* have fruits that begin ripening with a yellow color. They differ in that var. *aboriginum* remains yellow, while var. *simpsonii* changes to red when mature (Fig. 4).

3. *Cereus gracilis* var. *simpsonii* (Small) L. Benson, Cactus & Succulent Jour. 41: 126. 1969.

Harrisia simpsonii Small in Britton and Rose, The Cactaceae 2: 152. f. 223. 1920. Type: Florida. Monroe Co. Near Flamingo. May 1919. *J.K. Small* (lectotype NY).

This variety ranges from Everglades National Park south through the Keys. While Small and Benson have recognized 2 varieties within Florida (Long and Lakela, 1971 have their distribution reversed), the isolated populations and/or clones within the geographic range vary almost as much



Figs. 1-4. Spine length on *Cereus eriophorus* var. *fragrans*. Plants photographed in St. Lucie Co. (X 0.25). Fig. 2. Spine length in *Cereus gracilis* var. *simpsonii*. Plants photographed in Dade Co. (X 0.25). Fig. 3. Mature fruit of *Cereus eriophorus* var. *fragrans*. Plants photographed in St. Lucie Co. (X 0.5). Fig. 4. Mature fruit of *Cereus gracilis* var. *simpsonii*. Plants photographed in Monroe Co. (X 0.5).

as the 2 named varieties. Particularly, the southern plants seem to differ from those nearer the type locality in Everglades National Park. Fruit color, at least when fully ripe, will serve to separate the named taxa (Fig. 4).

In a few isolated areas within Everglades National Park there are good, reproducing populations of this taxon. Elsewhere, the stands are declining. Urbanization, bee-keepers and other factors have caused unprotected sites to decline abruptly; changing habitat seral stages also seem to have detrimental effects.

4. *Cereus robinii* (Lemaire) L. Benson, Cactus & Succulent Jour. 41: 124. 1969. Type: Cuba. Habana. *Robin* (holotype P, not seen).
Pilocereus robinii Lemaire, Illustr. Hort. XI. 1: misc. 74. 1864.
Cephalocereus robinii (Lemaire) Britton and Rose, The Cactaceae 2: 25. 1920.
Cephalocereus keyensis Britton and Rose, Contr. U.S. Natl. Herb. 12: 413. 1909. Type: Florida. Monroe Co. Key West. *Britton 518* (holotype NY).
Cereus robinii var. *deeringii* (Small) L. Benson, Cactus & Succulent Jour. 41: 126. 1969.
Cephalocereus deeringii Small, Addisonia 16: 39. pl. 532. 1931. Type: Florida. Monroe Co. Lower Matacumbe Key. 8 Apr. 1916. *J.K. Small 7790* (holotype NY; isotype US).

Britton and Rose (1920) delimited variation and species in the Florida populations in one manner; Small (1933) in another manner. Long and Lakela (1971) succeeded in confusing both of these approaches.

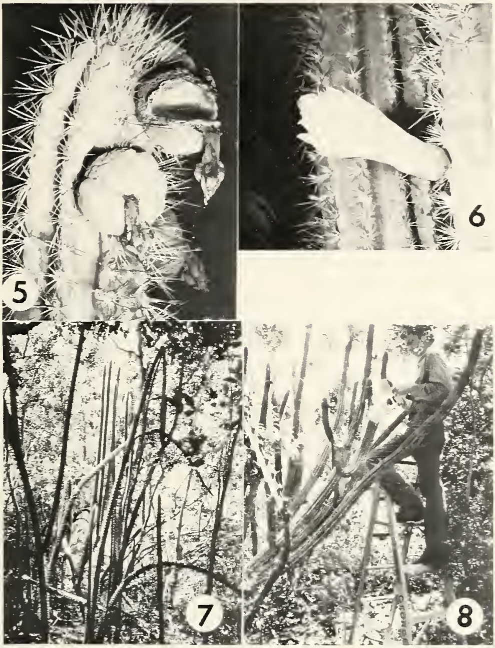


Fig. 5-8. Mature fruits of *Cereus robinii*. Plants photographed in Monroe Co. Fig. 6. Flower of *Cereus robinii*. Plants photographed in Monroe Co. Fig. 7. Habit of *Cereus gracilis* var. *simpsonii*. Plants photographed in Monroe Co. Fig. 8. Habit of *Cereus robinii*. Plants photographed in Monroe Co.

There may have been 2 varieties of *C. robinii* in Florida at one time, but I seriously doubt that there were. When J.K. Small first found the plants on the Matacumbes, it had not been long since a hurricane had passed. His photographs show plants with little-branched stems, and we found this typical of comparatively young individuals as well as wind-thrown plants. Both shading and young growth stands now result in few-branched plants. I believe that Small and others have considered the Matacumbe region plants as a distinct variety simply because their growth form was altered by environmental conditions. There is no evidence that they might have been genetically distinct from the lower keys populations. Now there are plants extant in the Matacumbe region that "should" belong to var. *deeringii* due to their geographic location. These individuals match the var. *robinii* in number of stem angles, numbers of spines per areole, and other traits. Individuals range from the branched condition in var. *robinii* to the unbranched condition of var. *deeringii*. Mostly, the degree of branching is a function of age or fallen main stems. When main stems fall, for whatever reason, the lateral branches produce the "unbranched" pattern of Small's concept of var. *deeringii*. As to pubescence differences, I have been unable to find plants that were not clearly referable to var. *robinii*. One of the complicating factors is that the indumentum is caducous. No matter how many infraspecific taxa one may recognize, the populations of the species are being reduced rapidly.

Some of the ways the plants may be taxonomically separated from *C. gracilis* are spine patterns, fruits, flowers, and habit (Figs. 5-8).

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AMPHITECNA LATIFOLIA (BIGNONIACEAE) IN FLORIDA—

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Abstract: *Black Calabash,* Amphitecna latifolia, *is reported in northern Palm Beach County at the north end of Lake Worth, a range extension of more than 160 km north of any previously known population in Florida. This population may be the result of an early horticultural introduction or it may be native to the area.*

Black Calabash, *Amphitecna latifolia* (Mill.) A. Gentry [*Enallagma latifolia* (Mill.) Small], is a tree of seashores, coastal hammocks, mangrove fringes and brackish-water swamps. It has been reported from southern Florida and the Florida Keys (Small, 1913 and 1933), Bermuda (Britton, 1918), through the West Indies (Grisebach, 1963; Moscoso, 1943; Urban, 1921) to Venezuela (Gentry, 1973; Little et al., 1974).

This species is rare in Florida with herbarium collections previously restricted to Dade County: Freeman Hammock, Arch Creek Prairie (*Small, Mosier* and *Small 6767*, FLAS) and Cutler Hammock (*Correll* and *Poponoe 47075*, FTG). A few reports of cultivated trees from Sanibel Island (*Brumbach 9418*, FLAS), Lee County, and Delray Beach (*Link*, 1932, FLAS), Palm Beach County, are known.

In 1975 while studying the successional patterns of the plant communities of Palm Beach County, a large population of Black Calabash was found at the north end of Lake Worth (T42S, R43E, Sec. 10). This population is confined to a shell mound underlain with limestone. The area supports many tropical species, most notably *Mastichodendron foetidissimum* (Mastic), *Simarouba glauca* (Paradise Tree), and *Bursera simaruba* (Gumbo Limbo). These species and 15 large trees of Black Calabash (15-38 cm d.b.h.) were found in various stages of maturity. Some of these trees had been uprooted and were suckering from the base. Several hundred young plants ranging from less than 1 m tall to over 1.5 m were found scattered throughout the site. A voucher specimen is deposited in the Florida Atlantic University Herbarium.

During visits on several occasions, open flowers were observed on the medium-sized trees, but no fruit was found. The flowers are normally pollinated by bats throughout most of their range, but no nectarivorous bats of this group are known from Florida (Stevenson, 1976). On 2 different occasions, blackbirds were observed pecking and tearing at open nectar-laden flowers. The large number of seedlings and the lack of bat pollinators suggests that pollination with fruit set has occurred via some other means, possibly by birds or other small mammals.

This population of *Amphitecna latifolia* extends the known range of this species almost 160 km north in Florida. Although Black Calabash has been reported as native in southern Florida, there are several facts suggesting it is introduced into Palm Beach County.

It was not until the following year while mapping the area that I noticed some broken glass near the center of the shell mound. Digging in the soil led to the discovery of several neatly placed rows of bottles which appeared to be of antiquity. Old historical accounts revealed that the bottles were used to manufacture an elixir called "Munyon's PawPaw." The elixir was apparently a combination of papaya and several medicaments which were sold to guests of Dr. Munyon's hotel.

Munyon's hotel was located about 1.6 km southwest of the Black Calabash site on a long and narrow island which was originally called Pelican, or Pitts, Island. In 1876, Nathan Pitts bought the island from a hermit and later built a rest home there for his sick wife. The island contains about 42 ha, beautifully situated with gently sloping shores, and looks directly out through Lake Worth inlet to the Atlantic. In writing about the island, as quoted by Carrie Pitts (1896), E. L. Briggs, correspondent of the Grand Rapids *Morning Press*, vividly described the many tropical trees which Mr. Pitts was cultivating around the grounds on the island: "Among these were orange, lemon, lime, guava-pawpaw, avocado-pear, fig, pomegranate, sour-sop, Chinese guava, sugar-apple, banana, maumee-apple, sapodilla, mango, mammi-sapota, tamarind, pineapple, coconut palm, cherimoya, wild good-plum, Spanish lime, scuppernong grape, date palm, sago palm, and several other kinds of tropical fruits. Growing wild were the custard-apple, mulberry, castor-bean, cherokee-bean, and calabash."

The island was later bought by Dr. Munyon who built a modest hotel for wintering guests from the North. It is possible that in order to conceal the production of his elixir, he chose a site further north beyond the bounds of his hotel. Brigg's account of "calabash" growing wild on the island suggests 2 possible plants: the true Calabash *(Crescentia cujete)* and Black Calabash *(Amphitecna latifolia)*. The fruits of true Calabash are gourd-like and have been used by several peoples in the tropics as drinking cups and various other domestic vessels; the fruit is emollient and astringent (Gentry, 1973), the seeds are cooked and eaten. The fruits of Black Calabash are much smaller and are not utilized in the same fashion as true Calabash; the pulp is also insipid and rarely eaten by humans.

It is conceivable that the source from which the present population of Black Calabash has sprung were plants cultivated by Dr. Munyon, the fruits or seeds transported by his workers to the elixir production site.

Because seed dispersal for Black Calabash is a result of water-dispersed fruits and mammal-dispersed seeds (Gentry, 1973), either means is sufficient to disseminate this species along the coasts of tropical Florida. The close proximity of the Gulf Stream to the lower Florida coast may account for this species in Palm Beach County and as far north as the island of Bermuda. Many tropical species have their northern limits in Florida controlled by their presence on calcareous soils, principally shell mounds (Harper, 1927; Long & Lakela, 1971). Therefore, this rather large population of Black

Calabash in Palm Beach County could be naturalized from an early introduction or it may be native to this area.

Acknowledgments—Thanks are due to Richard Wunderlin, Director of the University of South Florida Herbarium, for reading the original manuscript and making helpful comments and to the staff of the Historical Society of Palm Beach County for their assistance in obtaining historical documents.

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MOVEMENTS AND ACTIVITY PATTERNS OF A GRAY FOX IN SOUTH-CENTRAL FLORIDA

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ABSTRACT: *An adult male gray fox was radio-instrumented at Archbold Biological Station, Highlands County, on 24 December 1980, and its movements and activity were monitored intermittently until its death from canine parvovirus on 20 February 1981. Maximum home range was 2.69 km^2; maximum range length was 2.64 km. The fox was most active in early morning and late afternoon-evening, and least active during the middle of the day. Natural habitats were preferred to man-modified areas.*

WHILE studying the bobcat (*Lynx rufus*) at the Archbold Biological Station, 10 km S of Lake Placid, Highlands County, Florida, I live-trapped a 3.86 kg, adult male gray fox (*Urocyon cinereoargenteus*) on 24 December 1980. Following measuring and examination, the animal was fitted with a 150 g radio collar (AVM Model SB2:D) and released at the capture site. Its position was determined by radio tracking between 0830 and 2350 hrs on 38 occasions until 20 February 1981 when it was found in a moribund state. A description of equipment, procedures, and capabilities of the systems used are in Guenther (1980). Although the data are limited, they constitute the first quantitative information on daily movements and activity patterns of the species in Florida.

Home range, determined by the minimum polygon method,.was 2.69 km^2. Average distance between successive locations was 0.66 km (range 0-2.16 km), with 35 (89%) of the distances less than 1.21 km. Average distance between diurnal rest areas and nighttime activity locations was 0.83 km (range 0.24-1.46 km). Maximum range length and width were 2.64 km and 1.85 km, respectively. The length-to-width ratio of these axes (1.42:1) indicates the fox's home range was somewhat linear. Nineteen (50%) of all telemetry locations were in a 0.16 km^2 core area (maximum length and width: 1.24 km and 0.20 km) of dense shrub vegetation along a sand ridge centrally located within the delimited home range.

In Alabama, Sullivan (1956) recovered 3 adult female gray foxes an average distance of 0.93 km (range 0.4-1.6 km) from their original capture sites; Lueth (1962) recovered 38 gray foxes an average of 1.32 km from capture sites. In north Florida, Lord (1961) found that 24 of 28 recaptures (86%) during the first year were within 2.01 km of release sites. Although differences in methods do not allow direct comparisons between these studies, the results suggest that home range size of the southern Florida fox was comparable to that reported for gray foxes elsewhere in the southeastern U.S.

The fox was most active in early morning, late afternoon and evening, and tended to be least active between 1000 and 1400 hrs. Although no observations were made between midnight and dawn, the distances between locations recorded in late evening and early the following morning indicated that movements occurred during the unsampled period. All 10 presumed rest sites were in the core area. A den was not found, and strong radio signals during each of the rest periods suggested the fox was not below ground.

Nineteen (68%) of the telemetry locations during activity periods were in natural habitats: Slash pine-turkey oak woodlands (9), scrubby flatwoods (5), and flatwoods (5). Nine (32%) were in man-modified areas: Railroad right-of-way (3), old fields (2), and citrus groves (4). Other habitats in the area (bayheads, sand pine scrub, and improved pasture) were not contained in the delimited home range. Activity along the railway and in old fields may be related to high densities of cotton rats (*Sigmodon hispidus)* in these areas (J. N. Layne, pers. comm.). Activity in citrus groves occurred from 13 to 19 February.

On 20 February 1981, the fox was found in a weakened and emaciated state (weight 1.78 kg) in the yard of a rural residence 20 m from an open swimming pool; it died shortly thereafter. A necropsy performed at the Kissimmee Diagnostic Laboratory, Florida Department of Agriculture and Consumer Services, indicated the cause of death as canine parvovirus (CPV). Rapid dehydration is a typical symptom of this disease, which might account for the fox's location near a pool just before death and its activity in citrus groves containing operating water sprinklers during the preceeding few days. The winter of 1980-1981 was abnormally dry and open water sources were scarce. Nothing else unusual was noted in the fox's behavior. The identification of CPV as the apparent cause of death of this gray fox suggests that CPV should be recognized as a potentially significant mortality agent in wild canid populations.

ACKNOWLEDGMENTS—Support for this study was provided by Archbold Biological Station, Sigma Xi, Theodore Roosevelt Memorial Fund of the American Museum of Natural History, and Defenders of Wildlife, Inc., John H. Causey, D.V.M., arranged for the laboratory diagnosis which was performed by J. A. Rehkemper, D.V.M. James N. Layne read the manuscript and made helpful suggestions.

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NEW RECORD OF *ACIPENSER OXYRHYNCHUS* IN CHARLOTTE HARBOR, FLORIDA—*Thomas H. Fraser*, Environmental Quality Laboratory, Inc., 1009 Tamiami Trail, Port Charlotte, Florida 33952

ABSTRACT: *The Atlantic sturgeon is reported for the first time from Charlotte Harbor and is an extension of the known range.*

SYSTEMATIC fish surveys began in the Charlotte Harbor area about 1959 (Anon., 1959). Subsequent surveys were made by Woodburn (1960 a,b,c,), Phillips and Springer (1960), Woodburn (1961 a,b), Finucane (1965), Gunter and Hall (1965) and Wang and Raney (1971). These studies were summarized by Wang and Raney (1971), who listed 246 species for the area. The Atlantic sturgeon, *Acipenser oxyrhynchus*, was not included.

Huff (1975), in his description of the history of the sturgeon fishery in Florida along the Gulf Coast, described the activity that occurred in Tampa Bay, the nearest previously recorded locality. This fishery was economical only during the winter months and occurred from 1886 through 1889. Gilbert (1978) summarized the status of the 2 subspecies in Florida and lists the distribution on the Gulf Coast of Florida to Tampa Bay for *A. oxyrhynchus desotoi*. Gruchy and Parker (1980) also show the distribution of *A. o. desotoi* as extending to Tampa Bay.

An immature Atlantic sturgeon was caught 2000-2100 on 1 February 1982 in a 7.6m otter trawl by Robert H. Smyth. The net was towed between day marker 4 and red light marker 2 just west of the Barron Collier Bridge. The specimen has been placed in the Florida State Museum (UF 35113) at Gainesville. No salinity data are available for the capture date, however, the salinity probably was greater than 25‰ based on unpublished data from late January and early February in upper Charlotte Harbor.

Counts, measurements and qualitative features follow: fork length 972mm; head length 270mm; pectoral fin length 120mm; dorsal fin rays 39; anal fin rays 27; total gill raker 17; interorbit width 70mm; spleen length 90mm; mouth width 36mm; postdorsal and preanal shields 2 rows; peritoneum white; viscera mottled; anal fin pale; dorsal scute length shorter than width; dorsal scutes 7-10 with 1 strong hook, 1-6 without hooks.

This specimen exhibits characteristics of both subspecies and I am not sure which subspecies is represented. Based on similar data (*in litt.*) sent to me by Charles M. Wooley (U.S.F.W.S., Panama City) of a 840mm fork length specimen caught in the Apalachicola River, tagged and released, in April 1982, I am assigning the Charlotte Harbor specimen to the subspecies *desotoi*. The Apalachicola specimen had a head length of 250mm and left pectoral length of 108mm. These morphometric data, when expressed as percent fork length, are similar to those exhibited by the specimen I examined and both are low for *desotoi*. Morphometric and other data of these 2 specimens suggest that the difference described for specimens of both subspecies may break down with more material than Vladykov (1955) or

Vladykov and Greeley (1963) examined. These data include: head length, pectoral fin length, spleen length, scute shapes, keels and number of hooks.

There is no evidence to suggest that a population of sturgeon exists in the Charlotte Harbor area. However, based on Huff's (1975) description of spawning grounds, potential habitat does exist in the Peace River just above Arcadia where there is some shoal water with hard, rock bottom.

ACKNOWLEDGMENTS—The work was supported by General Development Corporation as part of its program relating to water quality in Charlotte Harbor.

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ERRATUM

On page 252 of *Florida Scientist* 46 (3/4, 1983), the figure used for Fig. 1 of Mulligan and Snelson's paper entitled, "Summer-Season Populations of Epibenthic Marine Fishes in the Indian River Lagoon System, Florida," is incorrect. The correct figure and caption are given below. We apologize to the authors for this error.

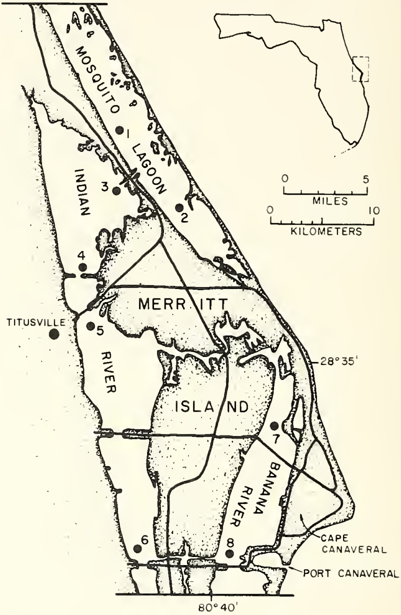

Fig. 1. Map of the northern portion of the Indian River lagoon system, Florida, showing the 3 lagoon basins, important landmarks, and 8 sampling stations employed in this study.

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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

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Volume 47 Spring, 1984 Number 2

Biological Sciences

STUDIES OF THE FLORIDA CONVOLVULACEAE— IV. *IPOMOEA*

DANIEL F. AUSTIN

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ABSTRACT: *Field and herbarium studies of the morning glory* (Ipomoea) *were made for Florida. Keys and illustrations are given for the state's 26 species.*

IPOMOEA contains about 500 species found in most temperate and tropical parts of the world. Because the genus is large and complex, it has been considered to be taxonomically difficult. Examination of the literature will show numerous interpretations, synonymies and differing concepts of species limits. The following material has been tested by a variety of people throughout Florida for about 6 yr. I have been told that it works, and several colleagues have urged me to make the material available. Because species descriptions will be forthcoming in the *Flora of the Great Plains* and the *Vascular Flora of the Southeastern United States*, they are not duplicated. The key and illustrations (Figs. 1-9) are offered as a prelude to these other treatments.

KEY TO SPECIES

1. Corolla salverform, the long narrow tube with sides more or less parallel, the limb abruptly flaring at the summit.
  2. Corolla 4-15 cm long, lavender to white; flowering at night or first part of the morning.
    3. Leaves tomentose beneath; corolla tube and limb mostly white outside; the tube lavender to purple inside; rare, found on middens. *I. macrorhiza* Michaux
    3a. Leaves glabrous; corolla white or lavender throughout; occurring on various sites.
    4. Sepals acute and at least the outer 2 caudate.
      5. Corolla lavender, the flower 3-7 cm long, weakly fragrant or odorless. *I. turbinata* Lagasca
      5a. Corolla white, the flower 10-14 cm long, strongly fragrant. *I. alba* Linnaeus

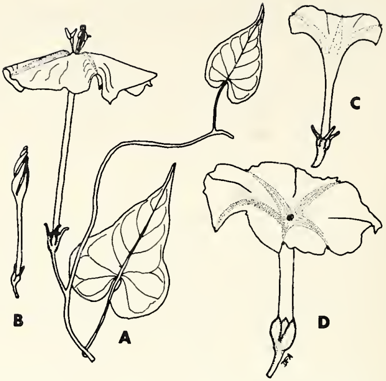

FIG. 1. Noctural flowers often confused. A. Habit of *Ipomoea alba*. B. Unopened bud of *I. alba*, often tinted green. C. Purple corolla of *I. turbinata*. D. White corolla of *I. macrantha*.

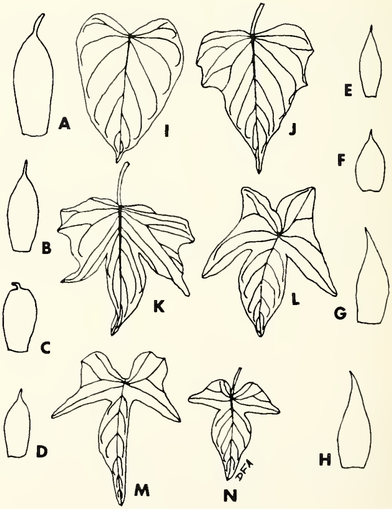

FIG. 2. Leaf and outer sepal variation in section *Batatas*. A-D. Sepals of *Ipomoea batatas*. E. Sepal of *I. triloba*. F. Sepal of *I. trifida*. G. Sepal of *I. trichocarpa*. H. Sepal of *I. lacunosa*. I-N. Some of the homologous leaf variation in the section.

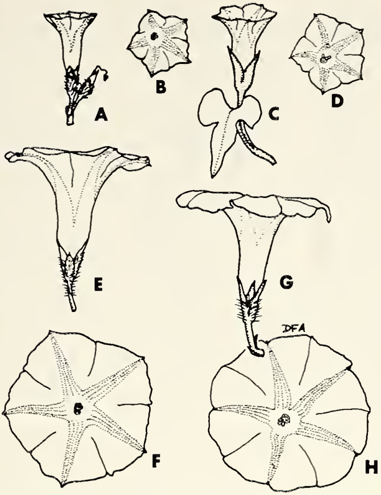

FIG. 3. Commonly confused species in section *Batatas*. A. *Ipomoea triloba*, lateral view. B. *I. triloba*, apical view. C. *I. lacunosa*, lateral view. D. *I. lacunosa*, apical view. E. *I. trifida*, lateral view. F. *I. trifida*, apical view. G. *I. trichocarpa*, lateral view. H. *I. trichocarpa*, apical view.

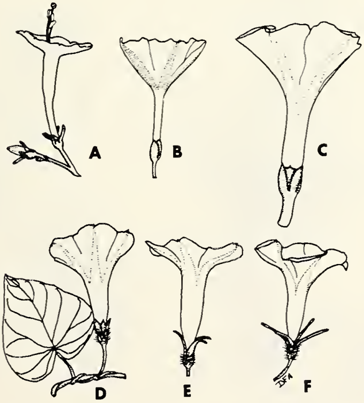

FIG. 4. Miscellaneous species. A. *Ipomoea hederifolia*. B. *I. microdactyla*. C. *I. setosa*. D. *I. purpurea*. E. *I. hederacea*. F. *I. nil*.

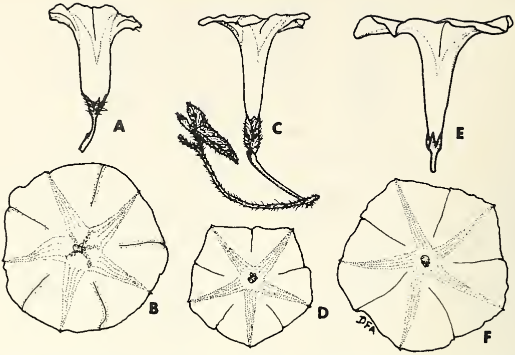

FIG. 5. Cultivated and rare species. A. *Ipomoea batatas*, lateral view. B. *I. batatas*, apical view. C. *I. tenuissima*, lateral view. D. *I. tenuissima*, apical view. E. *I. tricolor*, lateral view. F. *I. tricolor*, apical view.

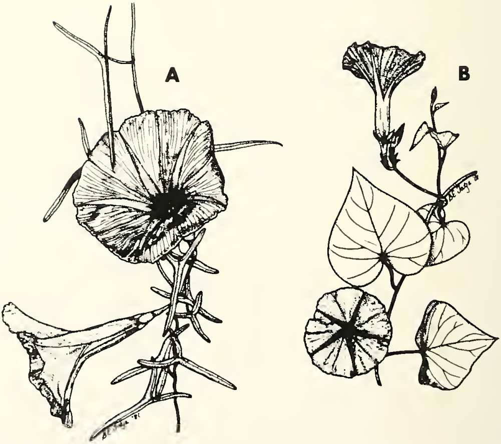

FIG. 6. Habit of 2 different twining species. A. *Ipomoea sagittata*. B. *I. indica*.

4a. Sepals obtuse, mucronulate.
6. Corolla white; stems glabrous; flowers opening before midnight. *I. macrantha* Roemer & Schultes
6a. Corolla lavender; stems setose with large fleshy trichomes; flowers opening mostly after midnight. *I. setosa* Ker-Gawler
2a. Corolla 2-4 cm long, scarlet, orange or yellow (rarely white in some cultivated forms of *I. quamoclit*); flowering all morning to all day.
7. Leaf blades divided more than half-way to midrib, the segments narrowly linear, appearing pinnately compound. *I. quamoclit* Linnaeus
7a. Leaf blades entire, angled or shallowly to deeply 3-7 lobed, the lobes broad or narrow but obtuse to acute.
8. Sepals acute and at least the outer 2 caudate.
9. Calyx 4-4.5 mm long; fruits erect. *I. hederifolia* Linnaeus
9a. Calyx (5-)6-8 mm long; fruits reflexed. *I. coccinea* Linnaeus
8a. Sepals acute to obtuse, mucronulate to mucronate, but never caudate. *I. microdactyla* Grisebach
1a. Corolla funnelform to campanulate, the short to long tube expanding from below the middle, the limb gradually or abruptly flaring at tube summit.
10. Gynoecium 3-parted; pedicels and peduncles with spreading, ascending or reflexed trichomes, rarely glabrous.
11. Sepals soft-pilose or pubescent on backs with slender trichomes, rarely glabrous. *I. indica* (Burmann) Merrill
11a. Sepals hispid-pilose on backs, the trichomes mostly with swollen bases.
12. Sepals with slightly narrowed green tips shorter to slightly longer than body. *I. purpurea* (L.) Roth
12a. Sepals with very narrow elongate green tips much longer than body.
13. Sepals abruptly narrowed, the long subacute tips strongly spreading or curved. *I. hederacea* Jacquin
13a. Sepals gradually narrowed, the long acute tips suberect, straight, scarcely spreading. *I. nil* (L.) Roth
10a. Gynoecium 2-parted; pedicels and peduncles glabrous or with appressed small trichomes.

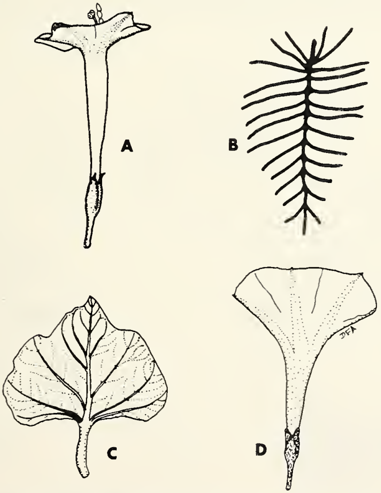

Fig. 7. Two species with salverform flowers. A. *Ipomoea quamoclit*, lateral view of flower. B. *I. quamoclit* leaf. C. *I. macrorhiza*, detail of lower surface of leaf. D. *I. macrorhiza*, flower.

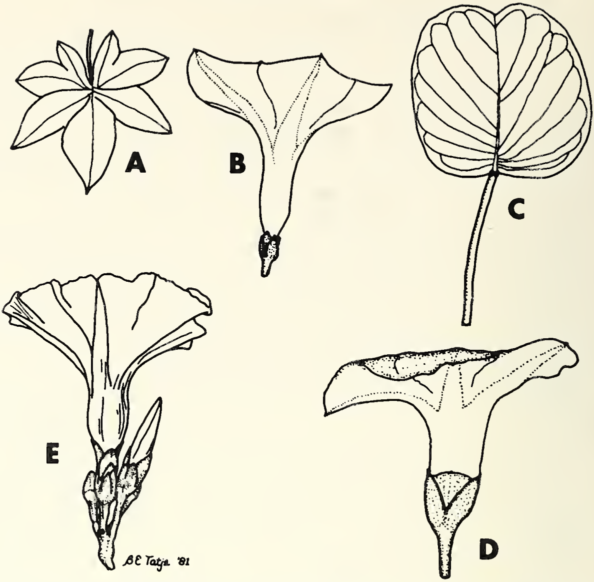

Fig. 8. Flowers and leaves of species with funnelform flowers. A. *I. cairica*, leaf. B. *I. cairica*, flower. C. *I. pes-caprae*, detail of lower surface of leaf. Note 2 black extra-floral nectaries at apex of petiole. D. *Ipomoea pes-caprae*, flower. E. *I. pandurata*, flower.

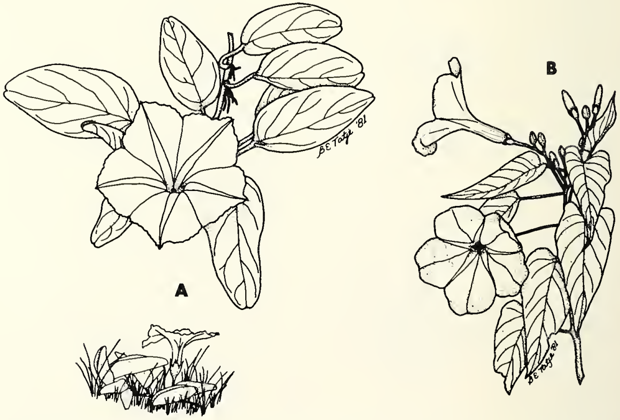

Fig. 9. Habits of a prostrate species and an erect shrub. A. *I. stolonifera*. B. *I. carnea* ssp. *fistulosa*.

14. Stems repent, rooting at the nodes; beach plants.
  15. Flowers lavender; leaves entire but deeply notched at apex. *I. pes-caprae* (L.) R. Brown
  15a. Flowers white with yellow to purple within the tube; entire with obtuse to truncate or emarginate apex to deeply and unequally 3-7 lobed. *I. stolonifera* (Cyrillo) Gmelin
14a. Stems erect or twining (repent and rooting at nodes in some *I. batatas).*
  16. Stems erect to scrambling, hollow. *I. carnea* ssp. *fistulosa* (Martius ex Choisy) D. Austin
  16a. Stems twining, not usually hollow.
    17. Leaves dissected with the segments lanceolate to triangular-lanceolate. *I. cairica* (L.) Sweet
    17a. Leaves entire or lobed.
      18. Leaf blades basally sagittate.
        19. Leaf blades glabrous; corollas 5-6 cm long. *I. sagittata* Poiret in Lamarck
        19a. Leaf blades pubescent; corollas 3-4 cm long. *I. tenuissima* Choisy in DC.
      18a. Leaf blades acute to cordate basally.
        20. Corollas to 2.5 cm long (hybrids between *I. lacunosa* and *I. trichocarpa* may key out here).
          21. Corollas white; anthers purple; sepals lanceolate. *I. lacunosa* Linnaeus
          21a. Corollas lavender; anthers white; sepals oblong to elliptic-oblong. *I. triloba* Linnaeus
        20a. Corollas mostly 3-8 cm long.
          22. Corolla limb blue, throat white to yellow; sepals triangular to triangular-ovate, margins scarious. *I. tricolor* Cavanilles
          22a. Corolla limb white to lavender, throat pink to purple; sepals ovate to oblong-elliptic or oblong-lanceolate, margins firm to chartaceous.
            23. Sepals ovate to oblong-elliptic; corolla usually white on limb with a purple throat. *I. pandurata* (L.) G. F. W. Meyer
            23a. Sepals oblong-ovate to oblong-lanceolate, acuminate to caudate; corolla usually pink to lavender on limb with lavender to purple throat.
              24. Sepals subequal in length, oblong-lanceolate, acuminate. *I. trichocarpa* Elliott
              24a. Sepals unequal in length, oblong-ovate, acute, to caudate.
                25. Corollas campanulate-funnelform, abruptly enlarged at calyx summit, lower half of tube with sides almost parallel, corolla 4-8 cm long; stems usually rooting at nodes in cultivated forms, but not in plants grown from seed. *I. batatas* (L.) Lamarck
                25a. Corollas funnelform, gradually enlarged at calyx summit, lower half of tube gradually increasing in diameter, corolla 3-4 cm long; stems not rooting at nodes. *I. trifida* (H.B.K.) G. Don

Florida Sci. 47(2):81-87. 1984.

SOME OBSERVATIONS ON ABNORMAL HEMOGLOBINS IN THE DEEP SOUTH

Curtis W. Wienker

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Abstract: *Hemoglobin and demographic data were obtained from 6,078 Black Americans tested in Tampa. Males comprised 41.7% of the sample; 58.5% was age 0-14 yrs and 35.9% was 15-44 yrs old. Genotypically, the sample was 88.91% AA, 9.64% AS and 2.45% AC, CC, SS or SC. For those within the sample of known birthplace, non-Southerners differ significantly from Southerners and non-urban Southerners, but not from urban Southerners as to genotype frequency. Rural Southern Blacks have the highest AS and total hemoglobinopathy frequencies; non-Southern Blacks have the lowest. Differential admixture of American Blacks and Anglo Americans is the most plausible primary explanation of this.*

Although Sickle Cell Anemia (SCA) has been known for less than 75 years, it is probably the best understood pathology to afflict man. The hereditary basis of SCA has been known for over 30 yrs (Beet, 1949) and the DNA and amino acid sequence of hemoglobin chains has been delineated (Huehns and Shooter, 1965). Furthermore, the relationship of the sickle cell allele (Hb^S) to malaria has been documented (Livingstone, 1958) and the intensity of selection associated with various hemoglobin genotypes in malarial environments is known (Cavalli-Sforza and Bodmer, 1971). Hb^S and other polymorphic hemoglobinopathies have been studied in scores of human populations world wide; the results of these surveys have been catalogued (Livingstone, 1967, 1973).

Livingstone's catalogues reveal that many studies have focused on Hb^S in Black American groups. Many of these studies have been primarily descriptive, focusing on a particular population of some anthropological interest (Pollitzer et al., 1970; Rucknagel, 1964). Others have focused on the evidence of continuing selection at the Hb locus (Workman, Blumberg and Cooper, 1963). Recently, Alfred (1980) has studied the dynamics of Hb^S in selected Black American populations.

The anthropological data on abnormal hemoglobins in Black American groups are usually derived from a "free-ranging" human population. Anthropologists typically study samples of intermating individuals who share common sociocultural parameters. Unfortunately, most studies of the abnormal hemoglobins, and Hb^S in particular, in Black Americans are based on data collected from clinically-derived samples. These clinical samples may not represent actual "free-ranging" human populations. The data from clinical samples may be biased and are best not used in studies of population dynamics.

While the data used in this report were collected by a county health department, they are not clinically based in that individuals comprising the sample did not visit a health care facility for any expressed purpose. Rather, in this case, a sickle cell screening program was conducted in a community setting solely for the purpose of screening for hemoglobinopathies, primarily to detect sickle cell trait (SCT) carriers. SCT individuals are heterozygous, with 1 allele for normal hemoglobin, Hb^A, and 1 sickle cell allele, Hb^S; genotypically they are Hb^A Hb^S, or more simply AS.

Other alleles exist at this locus, including Hb^C which is another infrequent, but not rare abnormal variant. SCT does not typically manifest itself symptomatically (Lin-Fu, 1972). The above suggests that the sample is more representative of a socioculturally indentifiable human population, rather than a more selective clinical one. The data are analyzed in terms of geography in order to understand historical factors bearing on population dynamics of this hemoglobin locus (sometimes called the ASC locus, after its major allele variants) in Black American populations.

METHODS—Blood samples were collected from 6,078 Black Americans in Tampa, as part of a community based sickle cell screening and genetic counseling program conducted in the early mid-70s. The samples were electrophoretically (Starch-gel) and densitometrically analyzed using standard techniques (Briere et al., 1965), in a mobile laboratory which was located in various places of community congregation from late 1972 through mid-1974. A total of 14,161 was tested. The 6,078 Black Americans comprising the sample are those for whom hemoglobin ASC locus genotype was determined electrophoretically and for whom some type of birthplace data were available. Prior to venipuncture, basic demographic data were solicited from each participant. As time permitted, state, county and city or town of birth was also collected.

Birthplaces considered to be urban were so assessed on the basis of 1960 census data. This year was chosen because it was the census year closest to the birthdate of most participants, over 50% of whom were under the age of 15 yrs. Birthplaces with a 1960 census of 50,000 or more were considered urban. The Deep South is defined to include Florida, Georgia, Alabama, Mississippi and South Carolina, the 5 southeasternmost states in the union.

Results—The distribution of hemoglobin genotypes by geographical region of birth is in Table 1. The sample consisted of 2,536 males (41.7%) and 3,542 females (58.3%); 3,543 (58.5%) were 0-14 yrs of age, 2,170 (35.9%) were 15-44 yrs old, 339 (5.6%) were 45 yrs or older and 26 were of indeterminate age.

The preponderance of females and young individuals is of no significant genetic consequence. Boyle et al. (1968) have shown there is no difference in

TABLE 1. Distribution of ASC hemoglobin locus genotypes by geographical region of birthplace.[1]

Region[2]	AA	%	AS	%	Other[3]	%	Totals
Tampa	3462	89.23	323	8.32	95	2.45	3880
Non-Tampa Florida	685	87.37	77	9.82	22	2.81	784
Non-Florida	1257	88.90	125	8.84	32	2.26	1414
Totals	5404	88.91	525	8.64	149	2.45	6078

[1] $X^2 = 2.6371$, 4df, $p > .50$.

[2] X^2 (Tampa vs. non-Tampa Florida) $= 2.2868$, 2df, $p > .25$. X^2 (Tampa vs. non-Florida) $= .4861$, 2df, $p > .75$. X^2 (Non-Tampa Florida vs. non-Florida) $= 1.2503$, 2df, $p > .50$.

[3] Includes SC, AC, CC, SS.

SCT prevalence by sex and no significant variation among age groups.

As Table 1 indicates, the differences between and among the subgroups within the sample, when grouped by geographical region of birth, are not statistically significant. However, when the sample is further broken down by birthplace, an interesting pattern emerges. These data are in Table 2. The relatively enormous Tampa-born group is omitted because its size statistically distorts realistic comparisons. The Deep South group, with its higher frequencies of homoglobinopathy genotypes (AS, AC, CC, SC, and SS) is highly significantly different from the non-Deep South group. Also, the non Deep South group is highly significantly different from the non-urban Deep South group.

Table 2. Distribution of ASC hemoglobin locus genotypes by birthplace, for subjects of known birthplace.[1]

Birthplace[2]	AA	%	AS	%	Other[3]	%	Totals
Urban Deep South[4]	152	90.48	14	8.33	2	1.19	168
Non-Urban Deep South	713	85.60	96	11.52	24	2.88	833
Total Deep South	865	86.41	110	10.99	26	2.60	1001
Non-Deep South	311	93.96	18	5.44	2	0.60	331
Total	1176	88.29	128	9.68	28	2.10	1332

[1] $X^2 = 18.0422$, 4df, $P < .005$.

[2] See Methods section for catagorization description.

[3] Includes AC, SC, SS, CC.

[4] Excluding Tampa-born. X^2 (South vs Non-South) $= 14.2864$. 2df, $P < .001$. X^2 (Urban vs. Non-urban South) $= 3.2158$, 2df, $p > .25$. X^2 (Non-South vs. Urban South) $= 2.0763$, 2df, $p > .25$. X^2 (Non-South vs. Non-Urban South) $= 16.1765$, 2df, $p < .001$.

The 3 distinct groups shown in Table 2, non-Deep South, urban Deep South, and non-urban Deep South, form a neat gradient with respect to AS, other and total hemoplobinopathy genotype frequencies. All 3 categories are lowest in the non-Deep South group (total = 6.04%) and highest in the non-urban Deep South group (total = 14.40%). The urban Deep South group is intermediate in each case (total = 9.52%).

DISCUSSION—The basic geographical patterns in hemoglobinopathy genotype frequency fit well with the general trends displayed by the data summarized in Livingstone's (1967, 1973) catalogues. The many studies of genotype frequencies at the ASC locus in Black Americans reveal a pattern whereby rural or non-urban Southern groups have the highest hemoglobinopathy frequencies and non-Southern groups have the lowest frequencies. Three factors may account for this general pattern: differential migration, differential selection, or differential admixture.

The S and C alleles in the Black American population are a result of its African ancestry. Thus, the differential migration hypothesis is based upon the assumption that Black emigrants from non-urban Southern areas to Southern cities and non-Southern destinations were less "African" in ancestry than non-emigrants. Pollitzer et al. (1970) have shown that emigrants from rural South Carolina to Charleston were probably relatively more

"African" in ancestry, genetically, in comparison to sedentary counterparts, suggesting that the differential migration hypothesis is false.

No data directly show that the differential selection hypothesis is true. This hypothesis assumes that hemoglobinopathic genotypes in the rural South had a selective superiority over those same genotypes in urban Southern or non-Southern environments, in terms of malaria. Rageb et al. (1966) suggested this as an explanation for high G6PD deficiency frequencies in rural Egypt, and Livingstone (1973) has claimed it as the primary reason for relatively high S frequencies in the rural South.

Malaria was pandemic to the South as recently as the 1920s (Farley 1970). According to Levine (1964) the disease was so prevalent and debilitating during the heyday of slavery that, at its peak during the fall months, few slaves were healthy enough to work in the fields. Thus, malaria as a selective mechanism may be responsible for the differences noted in Table 2, at least by indirect inference.

Considerable data exist which argue against this explanation. Livingstone (1971) and Serjeant (1974) claim the *Plasmodium falciparum* is the parasite associated with the selective advantage of the AS genotype in malarial environments. While *P. vivax* is known to have been present in the South historically (Livingstone, 1967), *P. falciparum* was probably common only in coastal areas (Russell, 1952).

If the AS genotype was selectively advantageous in the Southern malarial environment, the frequency of the S allele in rural (where mosquitos most readily breed) Southern Black populations should be relatively high in comparison to loci which have allegedly not been affected by selection in the past few hundred years. The work of Blumberg and Hesser (1971) and Workman et al. (1963) in rural Georgian Black populations suggests that the opposite is true. Their admixture estimates based on ASC locus data show that the frequency of the S allele is considerably lower than expected (and admixture estimates correspondingly higher) in comparison to loci supposedly not affected by selection (which yield "accurate" admixture estimates). Selection apparently does not adequately explain the differences in Table 2. However, its differential operation in rural vs urban environments (undocumented, to date), may contribute somewhat to differences in Table 2.

The most plausible explanation of the higher AS frequencies in the South and rural South is differential admixture. Rageb et al. (1966) suggest that the greater opportunity for admixture in urban settings may explain the prevalence of G6PD deficiency in Egypt. Estimates of European admixture have been calculated and summarized for several Southern and non-Southern Black American groups (Workman, 1973; Dyer, 1976). Of the 5 estimates derived from Southern Black populations, 3 focus on coastal or island groups which have been geographically and socially isolated and have very little admixture.

Two studies have focused on more typical Southern Black groups in Birmingham (Workman, 1973) and Evans and Bullock counties, Georgia

(Workman et al., 1963). These groups are comparable ecologically, historically and socioculturally to the urban Deep South and non-urban Deep South groups in Table 2. Moreover, they have relatively low admixture estimates (ca. 15% or less European ancestry) in comparison to the non-South admixture estimates (ca. 20% or more) based on Black American groups in New York City, Oakland (California), Detroit, Baltimore and Seattle. The patterns in Table 2 are apparently primarily due to differential admixture. Southern, and especially rural Southern Black American populations have less European admixture. Historical and census information provide insights into this pattern.

As Dyer (1976) notes, most of the admixture occurred in the 18th and 19th centuries. Until the 20th century, over 90% of American Blacks lived in rural areas, however over 50% of the non-Southern Blacks lived in urban settings. In 1950, over 90% of non-Southern Blacks lived in cities; less than 50% of Southern Blacks did. Prior to the Civil War, the overwhelming majority of "mulattos" were free, and concentrated outside the South (U.S. Dept. of Census, 1909). Except for a short time in the late 19th century, Southern states statutorily prohibited Black-White mating and marriage until the late 1960s. Sanctions against such unions were strong and penalties were harsh (Bennett, 1966).

The opportunities for admixture were greater in cities and urban Blacks were concentrated outside the South. Sanctions against and penalties for intermating were less stringent outside the South. Free Blacks were concentrated outside the South in cities. Just the opposite was true in the rural South where most Black Americans lived as slaves until the mid-1860s. The magnitude of the admixture differences must have been even greater than available studies indicate, for the differences remain evident despite the massive northern and western migration of rural and urban Blacks in the 20th century.

The differences may be accentuated to a degree by social selection. Herskovits (1926) suggests that lighter pigmented Blacks were preferred mates, at least among Blacks in New York City. This could have enhanced the fitness of non-Southern urban Blacks with less African ancestry. The opposite phenomenon may have characterized rural Southern Blacks historically. Pollitzer (1958) suggests that, in their case, social selection may have operated to enhance the fitness of individuals with more African ancestry.

The geographical variations in the hemoglobin data presented earlier are probably not the result on a single factor. However, differential migration is most likely not important. Differential selection may contribute to the geographical variation, but differential admixture appears to be the primary cause of the variation.

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DETERMINATION OF SEX FROM THE SACROILIAC JOINT: A VISUAL ASSESSMENT TECHNIQUE

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Abstract: *Assessment of sexual dimorphism in human skeletal remains is a major concern in paleodemography and forensic anthropology. This study is an attempt to develop a new visual sex determination technique based on the morphology of the posterior ilium and the sacroiliac joint. The sample is composed of 17 males and 10 females representing contemporary Americans and Asiatic populations. The analysis of the sample population is based on the anatomical variation between the sexes in the structures of the iliac tuberosity, the postauricular sulcus and the postauricular space formed by the articulation of the ilium to the sacrum. Results of the analysis indicate that the postauricular space, smaller in males, seems to be the most reliable structure for determination of sex. This is followed by the postauricular sulcus, a structure commonly present in females. The iliac tuberosity is the most varied structure and yet such a variation seems to be inherent in females rather than in males, the latter sex being uniform in shape and size.*

Anthropologists and anthropologically trained forensic pathologists should find the visually determined assessment technique of sexing an unknown human skeleton more practical than the osteometric techniques. The most obvious reason for this preference is the fact that complicated osteometry is not a mandatory requirement as long as the accuracy of correct sexing by the visual technique is reliable. Indeed visual determination of sex showed a 95% reliability (Phenice, 1969), a rate better than osteometric finding of 90% or less (Taylor and DiBennardo, 1982; Giles, 1970; Işcan and Shaivitz, 1982; Washburn, 1948).

We introduce another visual assessment technique that can be used in sexing a skeleton from the posterior half of the ilium and the morphology of the sacroiliac joint. The particular structures are the iliac tuberosity, the postauricular sulcus and the postauricular space.

Cleland (1889) may have been the first anatomist to refer to the postauricular sulcus in his analysis of the posterior iliac region. Yet, he did not mention the relationship of this structure to the sex of the individual. St. Hoyme (1963) is the anthropologist who noted the presence of dimorphism in the sulcus between the sexes, and Stewart (1979), in his recent book, illustrates this anatomical difference. The postauricular space considered by Derry (1911) is found to be smaller in males than in females. However, a survey of the literature indicates that no attention has been paid to the sexual variation in the shape of the iliac tuberosity.

Materials and Methods—Three osteological structures are chosen from the posterior segment of the ilium and sacroiliac joint (Fig. 1). The iliac tuberosity is medially located in the ligamentous surface of the bone which provides lodgment for the interosseus sacroiliac ligament (Breathnach, 1965). Immediately posterior and superior to this tuberosity is the enlarged iliac crest where the erector spinae muscle inserts. The surface superior to the tuberosity and anterior to the attachment area of the erector spinae is the insertion area for the quadratus lumborum muscle.

The second structure, the postauricular sulcus, is located between the iliac tuberosity and the posterior auricular surface being closer to the latter. When present this groove may begin at the vertical ramus of the auricular surface, continue along the horizontal ramus of the articular surface and terminate immediately superior to the posterior inferior iliac spine. The third structure, the postauricular space is an interosseus depression dorsally formed between the sacrum and ilium when a bone-to-bone articulation is constructed. This depression is filled by various ligaments including the short and long dorsal sacroiliac ligaments, at a deeper level the interosseus sacroiliac ligament, and superiorly the iliolumbar ligament (Woodburne, 1969).

Our sample size was 17 males and 10 females. Of the males, 3 were black, 10 were white, and 4 were Asiatic white. Of the females, 3 were black, 5 were white and 2 were Asiatic white. Except for the Asiatic whites which were obtained from a biological supply company all the specimens were recent forensic anthropological remains. Included in the same sample were 2 black adolescents (a 13 yr-old male and a 15 yr-old female) and a 15 yr-old white female.

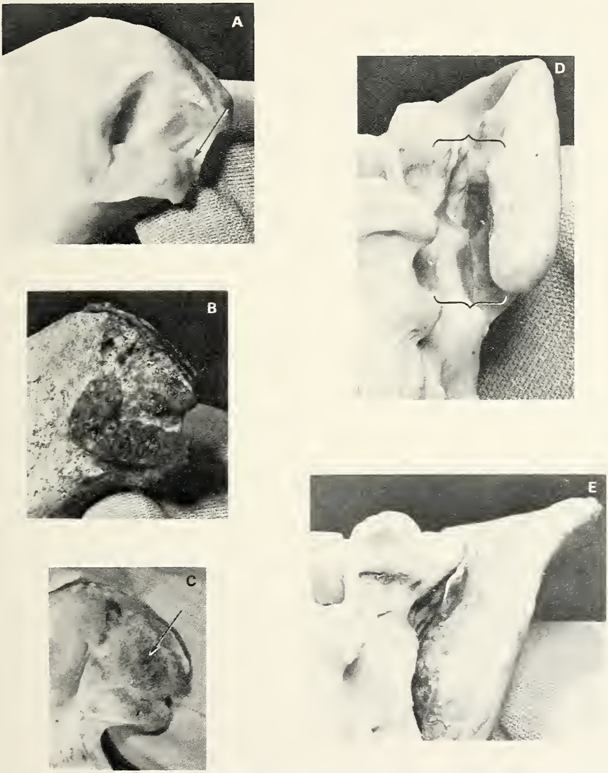

FIG. 1. Sexual dimorphism between females (A, B and D) and males (C and E). Arrows indicate the locations of the postauricular sulcus (A) and iliac tuberosity (C). Braces enclose the postauricular space (D).

Results and Discussion—Analysis of the data indicated that sex determination from the visual assessment of the posterior iliac bone and morphology of the sacroiliac joint is a new and promising technique that can be employed by both anthropologists and pathologists. Of the 3 structures, the most consistent one was the postauricular space. In all females, including the adolescents, the space between the posterior ilium and the sacrum was wider than that in the males (Fig. 1 D,E). This sexually dimorphic characteristic is due to the enlarged iliac tuberosity and/or greater anteroposterior thickness of the sacral ala in males resulting in a "tight" articulation. Furthermore, males formed 1 or 2 compartments separated by the iliac tuberosity. The superior compartment was more common than the double compartment in males. In the same sex, the inferior compartment rarely occurred alone. Females lack compartmentalization in the postauricular space.

The second consistent structure was the postauricular sulcus (Fig. 1 A,B,C). Of 10 females, 9 showed the structure well marked along the horizontal ramus. The depth of the sulcus was on the average 2 mm. The only female lacking this deep groove was the black adolescent female. This may have been due to the incomplete growth of the area particularly at the auricular surface. The epiphyseal union of the auricular surface could occur as late as 25 yrs. (Vyas et al., 1981). The same structure was observed in only 1 male along the horizontal ramus. Two males had the same structure only near the tip of the posterior inferior iliac spine. In the remaining males the sulcus did not exist and the bone transition from the auricular surface to the posterior ilium was smooth.

The third structure, the iliac tuberosity, was found to have greatest variation in females (Fig. 1 A,B,C). Males had this structure consistently shaped as a depressed "mound". The 2 most common forms in the females were a pointed mound-crest shape and a fossa without any bony prominence. The fossa formation may be attributed to the relocation of the attachment area of the ligaments rather than a lack of an osseus growth (Cleland, 1889). Of the females, 5 specimens had no iliac tuberosity indicating the fact that the ligamentous area was located along the iliac crest, and space for the tuberosity was fossa-like. In the remaining females, including the adolescents, the tuberosity was shaped as a pointed mound-crest.

The only obvious reason for such a sexual variation in the sacroiliac joint must be due to the adaptation of females to childbearing. During pregnancy ligaments of the pubic and sacroiliac joints become softer allowing for relaxation of these joints (Terry, 1942). This softening is related to the production of hormones produced during pregnancy (Abramson et al., 1934). The effect of the hormones is on the ligaments of both the symphyseal and the sacroiliac joints. Thorpe and Fray (1938) pointed out that there can be a differential widening of the 2 joints; that is, the sacroiliac joint could produce a mechanical separation, while the pubic symphyseal joint remains unseparated. However, there seems to be more attention paid to the symphyseal joint diastasis (Heyman and Lundqvist, 1932). Because of these hormones it is expected that the sacroiliac joint in females possesses a preadaptive capacity for childbearing which begins during adolescence. At the same time the size of the iliac tuberosity is reduced, and the auricular surface of the ilium is elevated. This last process eventually results in the formation of the postauricular sulcus. Total outcome of this growth and preadaptation to pregnancy is seen in the widening of the postauricular space.

The significance of such a change should be seen as a widening of the symphysis and a narrowing of the distance between the posterior ilia. This adaptive morphology of females shows its utmost effect during parturition. The second important aspect of the sacroiliac joint is seen also in pregnant females. During pregnancy a motion between the ilium and sacrum is increased (Goldthwaite, 1907). This increase seems to be due to the tilting of the sacrum on the ilia which results in the enlargement of the conjugate diameter and transverse breadth of the pelvic brim. The fossa formation in the place of the tuberosity may be a secondary adaptation to the stress of pregnancy. This fossa and the reduced size of the tuberosity may result from the functional reaction of the erector spinae muscle and to some extent, the quadratus lumborum muscle.

In summary, the posterior iliac bone and its articulation with the sacrum can be used to determine sex. Of 3 structures considered in this study, the postauricular space seems to be the most reliable.

This observation can be enhanced by the presence of the postauricular sulcus continuing along the horizontal ramus. Furthermore, the presence of a fossa instead of the tuberosity should also be considered as a female characteristic.

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Earth Sciences

SOILS OF SWAMPS IN THE APALACHICOLA, FLORIDA, ESTUARY

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Abstract: *Selected soils in swamps of the Apalachicola, Florida estuary were sampled and analyzed. Three great groups, Sulfihemists, Sulfaquents, and Fluvaquents were found. These soils were wet, moderately acid, high in clay content, and low in salinity. Kaolinite, vermiculite, quartz, and mica were the principal clay-sized minerals. Decisions concerning agronomic utilization of these soils should be carefully made because of their high potential acidity, low-bearing strength, and frequent flooding.*

Forested wetlands are common in Florida. Until recently these wetlands were classified as miscellaneous land types or as broadly-defined soil series. Recent interest in wildlife, recreation, urban development, and water management has resulted in a more detailed inspection and mapping of these soils.

Extensive areas of Sulfihemists, Sulfaquents and Fluvaquents occur in marshes of the Apalachicola estuary (Coultas, 1980). In this area the soils closest to the river were non-saline, while those further away from its influence were saline-alkaline. Smectite was the predominant clay-sized mineral. Haplaquepts were found on the Apalachicola River floodplain approximately 35 km north of the site of the present study (Coultas, 1977).

These soils were occupied by tupelo gum, ogeechee tupelo and bald cypress. Kaolinite was the predominant clay mineral in this soil.

I characterized and classified selected soils of swamps in the Apalachicola estuary. This information should lead to a better understanding of these soils and prove valuable in the management of wetlands.

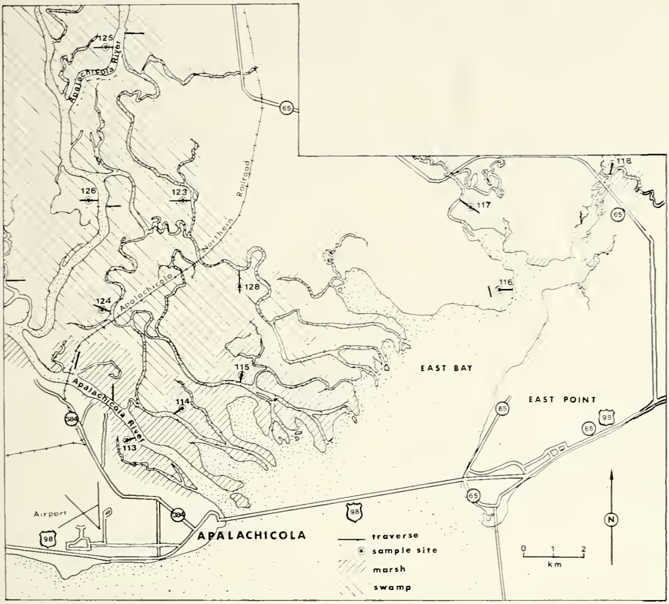

FIG. 1. Location of traverses and soil sampling sites in the Apalachicola, Florida estuary.

MATERIALS AND METHODS—Several traverses were made from the lower to upper reaches of the swamps of the Apalachicola estuary and the variability of soil properties was noted. Representative soils were sampled at 5 sites (Fig. 1) with a bucket-type auger and described as outlined in the Soil Survey Manual (Soil Survey Staff, 1951). Brief descriptions are in Table 1. The following standard laboratory determinations were performed on soil samples from all horizons: pH (Jackson, 1958), particle size analysis (Day, 1965), electrical conductivity (EC) (Jackson, 1958), organic carbon (C) and loss on ignition (Jackson, 1958), total N (Bremner, 1965), cation exchange capacity (CEC) and extractable cations (Jackson, 1958). Soil acidity was determined on the field moist (un-dried) and air-dried soil. Soluble salts were removed with an alcohol wash previous to extracting the cations and CEC was determined with 1N NH_4OAc at pH 7.0. Before particle-size was determined organic matter was destroyed with H_2O_2. Total sulfur (S) was determined on selected horizons with a Leco (SC-32) S analyzer (Tiedman and Anderson, 1971).

Clay separates of the soils were segregated, according to the procedures described by Jackson (1958). Two sets of parallel oriented samples, one Mg-saturated, glycerol-solvated and the other K-saturated with and without heat were prepared on glass slides. X-ray diffraction patterns were obtained using a General Electric XRD-7 instrument and Ni-filtered Cu-radiation. Identification of the clay minerals was made according to the procedures of Whittig (1965). Soils were classified following criteria outlined in Soil Taxonomy (Soil Survey Staff, 1975).

TABLE 1. Morphological properties of soils in the swamps of the Apalachicola estuary.

Horizon	Depth in cm	Predominant Moist Color	Texture*	Structure+	Consistency^s	Roots	Location
			Pedon 123				
Oa1	0-20	10YR 4/2	o	sbk	ss	abundant	SE¼ sec. 36
C1	20-42	10YR 5/2	c	m	s	abundant	T7S, R8W
Oa2	42-80	10YR 3/2	o	m	ss	common	Franklin County
Oa3	80-150	10YR 2.5/1	o	m	ss	few	
			Pedon 124				
A1	0-30	10YR 5/2	c	sbk	s	abundant	NW¼ sec. 14
Oa1	30-50	5YR 2.5/2	o	m	ss	abundant	T8S, R8W
A11bg	50-100	5Y 2.5/1	c	m	ss	common	Franklin County
A12bg	100-150	5Y 3/1	sic	m	s	few	
			Pedon 125				
A11g	0-2	5Y 5/2	c	m	ss	abundant	Between Little Brother
A12g	2-40	5Y 6/1	c	sbk	s	abundant	Slough & Apalachicola R.,
A13g	40-95	5Y 5/1	c	m	s	common	approx. 200 m. west of
A14g	95-125	5Y 5/1	c	m	s	few	river. T7S, R8W
			Pedon 126				Gulf County
A11g	0-2	5Y 4/2	c	m	ss	abundant	Between Johnson Slough
A12g	2-32	5Y 5/2	c	m	s	abundant	and Apalachicola R.,
A13g	32-65	5Y 5/1	c	m	s	common	approx. 200 m. west of
Oag	65-100	5Y 4/1	o	m	ss	common	river. T8S, R8W
A1bg	100-150	5Y 3/1	c	m	ss	few	Gulf County
			Pedon 128				
A11g	0-15	5Y 4/1	c	m	ss	abundant	SW¼ sec. 7
A12g	15-50	5Y 3/1	si	m	ss	abundant	T8S, R7W
A13g	50-75	5Y 2.5/1	c	m	s	common	Franklin County
C1g	75-120	5G 4/2	c	m	s	common	
C2g	120-150	5G 4/2	c	m	s	few	

* o = organic, c = clay, sic = silty clay, si = silt.
+ sbk = sub-angular blocky, m = massive.
s ss = slightly sticky, s = sticky.

Table 2. Particle size and "n" value of soils in the swamps of the Apalachicola estuary. Numbers represent percentages, except for "n" values.

Horizon	Sand					Silt	Clay	Texture*	"n" value**
	Very Coarse	Coarse	Medium	Fine	Very Fine				
Pedon 123									
Oa1	—	—	—	—	—	—	—	o	—
C1	—	—	—	—	—	8.1	91.9	c	1.4
Oa2	—	—	—	—	—	—	—	o	—
Oa3	—	—	—	—	—	—	—	o	—
Pedon 124									
A1	—	—	—	0.7	0.8	13.9	84.6	c	1.1
Oa1	—	—	—	—	—	—	—	o	—
A11bg	—	—	—	1.2	8.4	45.2	45.2	c	1.9
A12bg	—	—	—	1.8	14.6	43.7	39.9	sic	2.2
Pedon 125									
A11g	—	—	—	—	—	34.0	66.0	c	2.0
A12g	—	—	—	—	—	23.0	77.0	c	1.0
A13g	—	—	—	—	0.6	24.5	74.9	c	1.4
A14g	—	—	—	—	0.5	25.2	74.3	c	1.6
Pedon 126									
A11g	—	—	—	—	—	16.3	83.7	c	3.2
A12g	—	—	—	—	—	21.9	78.1	c	1.7
A13g	—	—	—	—	—	21.9	78.1	c	1.5
Oag	—	—	—	—	—	—	—	o	—
A1bg	—	—	—	—	—	37.9	62.1	c	3.3
Pedon 128									
A11g	—	—	—	0.4	4.1	22.2	73.3	c	2.2
A12g	—	—	0.2	1.8	10.9	70.0	17.1	si	4.4
A13g	—	—	—	1.7	19.9	8.4	70.0	c	1.4
C1g	—	−0.2	—	2.5	19.9	34.7	42.7	c	1.3
C2g	—	—	—	17.0	17.6	13.6	51.8	c	1.4

* o = organic, c = clay, si = silt, sic = silty clay.

** $n = \frac{A - 0.2R}{L + 3H}$ where A = % of water in soils under field conditions, R = % silt + sand, L = % clay, H = % organic matter.

TABLE 3. Selected physical and chemical properties of soils in the swamps of the Apalachicola estuary.

Horizon	pH		EC	Total S	Field moisture
	Field moisture	Air dry			
			mmhos/cm	----------- %	-----------
Thermic Pedon 123 Typic Sulfihemist					
Oa1	5.6	4.2	0.1	3.22	245.5
C1	5.8	4.5	0.4	—	184.0
Oa2	6.1	3.9	2.9	3.40	558.0
Oa3	6.3	4.5	5.4	—	427.4
Pedon 124 Typic Sulfaquent					
A1	5.5	4.6	0.9	—	166.2
Oa1	6.0	4.6	5.3	1.94	592.7
A11bg	6.2	5.7	7.5	—	226.8
A12bg	6.3	5.7	7.7	1.39	182.8
Pedon 125 Typic Fluvaquent					
A11g	6.0	4.2	0.7	0.10	210.6
A12g	4.9	4.7	0.2	0.04	99.8
A13g	5.6	4.0	0.8	0.16	160.3
A14g	5.6	4.4	2.3	—	188.0
Pedon 126 Typic Fluvaquent					
A11g	5.4	3.7	0.2	—	550.8
A12g	5.8	4.1	0.1	0.27	190.8
A13g	5.4	3.9	0.1	0.13	158.3
Oag	6.2	4.2	0.2	1.62	309.3
A1bg	5.8	4.6	0.7	—	377.9
Pedon 128 Typic Sulfaquent					
A11g	5.7	4.8	0.2	0.15	312.0
A12g	5.6	4.2	0.2	3.50	330.7
A13g	6.0	4.0	0.5	0.33	148.0
C1g	6.4	4.6	1.7	—	73.2
C2g	6.1	3.6	—	—	90.6

CEC	Extractable cations				Total N	Ignition Loss	Organic C
	Ca	Mg	K	Na			
meq/100g					%		
55.53	13.5	3.3	0.5	0.5	0.76	33.2	17.89
35.76	7.9	6.1	0.7	1.2	0.46	18.2	7.38
93.39	31.2	20.0	0.6	6.0	1.51	43.3	30.80
65.81	19.9	18.9	0.9	6.7	0.94	33.4	18.44
	72.5	48.3					
49.74	10.2	8.0	0.7	1.8	0.78	27.8	12.92
94.04	24.3	26.2	1.0	10.7	1.44	39.1	24.40
50.36	14.3	18.4	1.2	7.9	0.52	35.6	12.85
35.94	8.6	14.0	1.1	6.8	0.34	14.4	7.62
	57.4	66.6					
38.04	13.9	1.4	0.9	0.3	0.45	14.2	7.47
30.74	6.1	0.9	0.2	0.2	0.07	8.7	2.71
35.96	10.0	1.6	0.1	0.3	0.39	14.0	7.02
40.55	16.5	3.6	0.1	0.8	0.34	13.2	7.81
	46.5	7.5					
74.92	11.8	2.0	0.4	0.4	0.84	29.0	16.76
30.39	5.7	1.1	0.2	0.2	0.47	13.5	6.46
33.50	5.7	1.0	0.2	0.4	0.32	11.6	4.94
64.16	11.4	14.0	0.4	2.5	0.78	30.0	18.64
45.51	18.1	1.7	0.5	0.2	0.56	17.9	9.54
	52.7	19.8					
41.01	12.4	4.6	0.7	0.7	0.74	25.3	12.66
35.38	9.6	6.8	0.5	0.5	0.52	20.1	10.36
31.66	7.6	7.0	0.4	0.5	0.33	14.0	6.58
29.98	7.9	6.8	0.4	0.8	0.10	4.9	0.86
27.92	4.9	7.4	0.4	0.5	0.07	5.5	1.42
	42.4	32.6					

Results and Discussion—The vegetation of the Apalachicola estuarine swamp consists of several woody plants, with swamp chestnut oak (*Quercus prinus*), red maple (*Acer rubrum*), tupelo gum (*Nyssa aquatica*), Carolina ash (*Fraxinus caroliniana*), bald cypress (*Taxodium distichum*), and cabbage palm (*Sabal palmetto*) being most common. Clumps of wax myrtle (*Myrica cerifera*) and saw palmetto (*Serenoa repens*) also occur. Arrowleaf (*Sagittaria* spp.) and plants of the amaryllis family also are common. Other factors of soil formation in this estuary were previously presented by Coultas (1980).

Soils of the swamps of the Apalachicola estuary are very poorly drained and contain large amounts of clay and organic matter (Tables 2 and 3). These soils have been formed from recent accumulation of sediments deposited in stream channels and estuarine meanders. They are highly mixed, with little structural development, and have very high (>1) "n" values, which indicates that they have never dried in place. Consequently, these soils have very low–bearing capacities for large animals and machinery.

Field moist pH values for all soils ranged from 4.9 to 6.6 and were within the typical range for marine sediments (Berner, 1967) and tidal marsh soils (Fleming and Alexander, 1961). Upon drying, the reaction of these soils underwent further acidification and became 0.2 to 2.5 pH units lower. This acidification most likely was due to the oxidation of S and S-containing compounds. Total S ranged from 0.04% in the A horizon of pedon 125 to 3.50% in the A horizon of pedon 128.

Salt content varied considerably as evidenced by the conductivity values (Table 3). These values increased from the surface downward as may be expected because the surface tends to be frequently flushed with rain and river waters resulting in a dilution of salts. Only pedon 124 was saline. River flow and low tidal amplitude probably account for this low salinity in most soils.

Of the extractable bases, Ca was the most abundant, with Na in much higher concentration than K (Table 3). This agrees with the findings of Coultas and Gross (1975), although, in a previous study Coultas (1969 and 1970) reported higher values of Mg over Ca. The cation exchange capacity usually varied directly with the organic C content.

These soils contained high amounts of organic C and total N; pedon 125, the soil furthest upriver, contained the least N and C. Organic C did not usually decrease uniformly from the surface horizons downward indicating the variability of these alluvial deposits. Loss on ignition confirmed the high organic matter contents and usually resulted in higher organic C estimates, probably due to loss of occluded water. Although elevation was not determined, pedon 125 is probably the highest. This less humid environment resulted in lower levels of organic C, N, and S.

Clay Mineralogy—The diffractograms (Figs. 2 and 3) of 2 representative pedons show the predominance of kaolinite and vermiculite (or intergrade) in the clay fraction in contrast to the predominance of smectite in the marshes at Apalachicola (Coultas, 1980). The presence of mica in all pedons

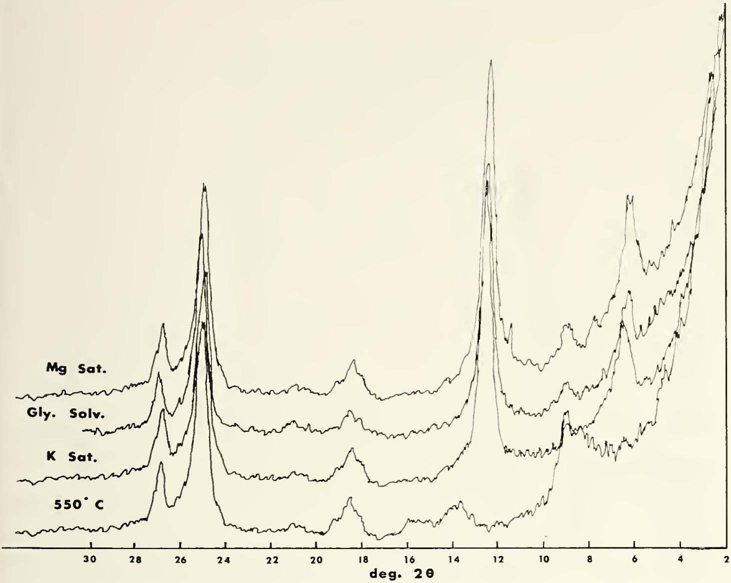

FIG. 2. X-ray diffractograms of clay-sized particles from the Al horizon of pedon 124. Four treatments were employed: Mg saturation with and without glycerol solvation, K saturation at room temperature and at 550°C.

is confirmed by a persistent 10.0Å peak in all treated samples. I postulate a winnowing effect of the clays, with the soils formed in the quieter, lower energy waters of the estuary (marshes) containing high amounts of smectite (Coultas, 1980), while the larger kaolinite particles are dropped in the swifter waters of the swamps.

CLASSIFICATION OF SOILS—Pedons 123, 124, and 128 being noncalcareous and containing more than 0.75% S (dry weight) in the surface 50 cm are classified as sulfidic. Pedon 123 is classified in the euic thermic family of Typic Sulfihemists. Pedon 124 is classified in the fine, kaolinitic, non-acid, thermic family of the Typic Sulfaquents, while pedon 128 is fine, mixed, non-acid, thermic family of Typic Sulfaquents.

Pedon 125 is placed in the very fine, mixed, non-acid thermic family of the Typic Fluvaquents. Pedon 126 is the same family as pedon 125 but is in the Thapto-Histic Fluvaquents sub-group. Although sulfidic material occurs within 1 m of the surface, it has a buried histic epipedon which is separated from "typic" before soils with sulfidic materials.

Soils of the swamps of the Apalachicola estuary are similar in classification to marsh soils occurring down-river. More Sulfihemists probably occur

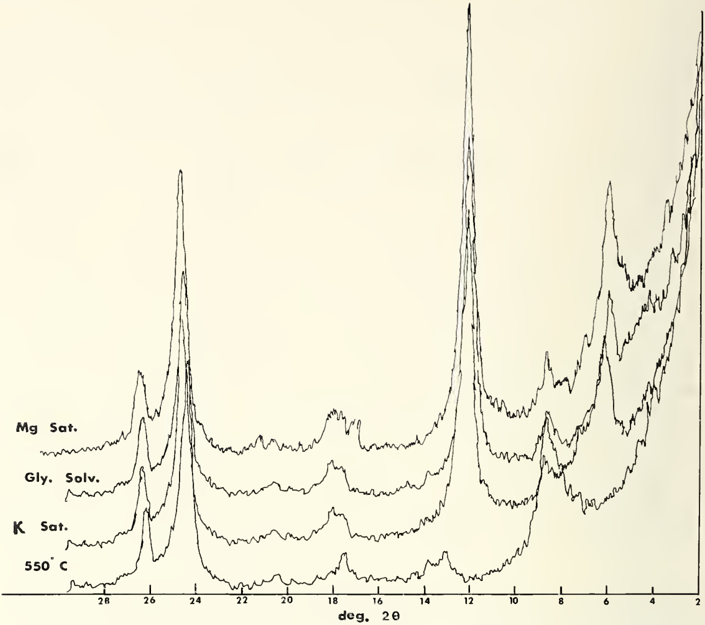

Fig. 3. X-ray diffractograms of clay-sized particles from the A12g horizon of pedon 125. Four treatments were employed: Mg saturation with and without glycerol solvation, K saturation at room temperature and at 550°C.

in the marshes, however, and the soils of the swamps contain more clay and tend to be more acidic than soils of the marshes.

Land Use—The soils are wet and subjected to daily tidal flooding. Movement of machines and animals over these areas is limited due to the low-bearing strength of the soils ("n" value >0.7). This would limit their agronomic utilization. The high cation exchange capacity of these soils indicates a high potential for adapted plants as well as a sink for trapping cations. Heald and Odum (1969) have demonstrated that fish and invertebrates use the detritus produced in swamps as a food source. The swamps also act as a barrier against storm erosion of the adjacent uplands.

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FATHER CUSTODY AND MIDDLE-CLASS REBELLION

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Abstract: *Based on Merton's theory of social structure and anomie, I hypothesize that father custody will occur predominately among middle-class divorced couples. Father custody is viewed as not only a rejection of traditional parental roles, but also as a rebellion against cultural values concerning the role of the family in society. A sample of 101 divorced fathers in Central Florida was used. The hypothesis that father custody would occur more frequently among the middle class was supported. Of 5 variables examined only religion indicated a possible influence on custody. The findings are compared with other information on family change and the importance of class structure as a determinant of family structure is upheld.*

The systemic nature of the relationship between family structure and other institutional arrangements has been a major concern of family theorists. While the nature of this relationship is the source of considerable debate, the emphasis has been placed on a causal relationship in which changes in family structure are determined by the needs of the economy for workers (Holter, 1974).

This emphasis on the adaptation of the family to extra-systemic influences has limited family sociologists from considering family events as independent variables affecting extra-familial systems (Lee, 1974). Lee employs Merton's (1968) concept of social structure and anomie to test hyotheses relating marital satisfaction and social class. By utilizing Merton's theoretical paradigm, I examine father custody as a class-specific case of anomie. This anomie produces rebellion against cultural values regarding the structural position of men and women in the family and the specific roles assigned to those positions.

Merton points out that social and cultural structures contain 2 elements. The first consists of culturally–defined goals and the second of modes or institutional means of meeting those goals. While both reflect cultural values, the values represented by the norms which regulate conduct serve to limit the choices available for attaining goals. His main hypothesis is that nonconforming behavior may be seen as a dissociation between cultural goals and institutionalized means.

Merton developed a five-stage typology of individual modes of adaptation with the last 4 producing a strain towards anomie created by failure to achieve goals, effect means, or both. Three of these deviant modes of adaptation are associated with a specific class structure.

The fifth mode of adaptation is rebellion, which is defined as a "rejection of prevailing values and the substitution of new values" with reference to both goals and means. Merton presupposes that alienation from established goals and standards occurs when these goals and standards come to be seen as purely arbitrary. As a result, neither goals nor means are seen as legitimate and the response is a rebellion that seeks to modify the social structure. Merton predicts that rebellion will occur among a middle-class with rising expectations.

CHANGES IN FAMILY STRUCTURE—Changes in the structure and function of the family in this century have been both real and imaginary or, if not imaginary changes, then they may more appropriately be defined as fads and foibles. Real changes include a reduction in family function (Ogburn and Tibbets, 1934), reductions in family size, increased participation of wives and mothers in the labor force (Current Population Reports, 1979), and an increase in one-parent families (Ross and Sawhill, 1975). Other "alternatives" that were touted as the wave of the future, such as group and communal marriages, and swinging have disappeared from both popular and academic consideration (see Ramey, 1972; O'Neill and O'Neill, 1972). The recent interest in father custody has been reflected in television programs, the movie *Kramer vs. Kramer*, and in the popular press (see Victor and Winkle, 1977 and Noble and Noble, 1975).

The academic literature has largely been concerned with the legal aspects of father custody and clinical concerns of the effect of father custody upon children and parents (Sell, 1981). In spite of all the attention the issue has received, the percentage of fathers holding custody has remained constant over the past 2 decades, although the absolute number has increased (Current Population Reports, 1979). Thus the question of whether father custody represents rebellion or fad is unclear. I will assume that father custody is but 1 manifestation of a rejection of long-standing cultural ideologies relative to the appropriate position of adult males and females within the family.

Dahlstrom (1971) traces 6 traditional ideologies which specify suitable familial roles. These include the Judiac/Christian tradition, early liberal, romantic, Marxist, moderate, and radical ideologies. With the exception of the Marxist and radical ideologies, these ideologies all differentiate male and female familial roles according to instrumental or expressive functions. The historical development of these ideologies indicates a movement over time toward legal and political equality. Attempts have been made to bridge the gap for women striving to achieve both instrumental and expressive roles, but the nurturing role remains firmly attached to the maternal position.

Father custody releases the mother from the expressive role, allowing her to pursue instrumental roles free of nurturing responsibilities. By increasing the father's expressive responsibilities, custody threatens his instrumental functioning which places him in the position of the working mother who may have to give nurturing tasks precedence over job responsibilities.

Deep-seated cultural biases against the assignment of father custody have been observed among lawyers and judges (Gersick, 1979; Weiss, 1975). In spite of amended statutes in many states which reject both the "tender years" and "innocent party" doctrines, there is still a noted resistance on the part of judges, investigators and divorcing couples themselves to father custody awards (Pearson et al., 1982). Assuming a rejection of cultural values concerning family functions (nuturance and socialization) and having some evidence of rebellion against the traditional male-instrumental and female expressive roles, Merton's theory can be used to construct a hypothesis. Middle-class divorced parents will be more likely to reject traditional custody arrangements than either upper-class or lower-class divorced parents.

METHODS—A sample of 101 men was selected from a population of divorced and remarried men in central Florida who were between the ages of 25 and 45. The selection was limited to men who have been divorced at least 1 yr and had at least 1 child by a previous marriage. The sample was drawn from 4 sources. Twenty-one names were obtained from a social service agency in Orlando serving divorced men. Contacts with these men resulted in only 3 completed interviews because most of them had moved. A second list of names was obtained from the marriage license applications in Orange and Seminole counties. Five hundred and ninety-nine names were selected. Of these, only 187 could be tentatively identified through telephone and city directories. Thirty-nine interviews were completed from this list. The remainder could either not be located, or had no children by their first marriage, or would not participate in the study.

Twenty more respondents were found by word of mouth from among my friends and associates. Finally, a story explaining the research project appeared in the *Orlando Sentinel*. This story requested men to call for an interview if they were interested in participating in the study. Forty-eight calls were received and 40 interviews completed. The data collected from these four sources were obtained in the summer of 1979.

Respondents were asked if they had ever had legal custody of 1 or more of their children at any time following the divorce. Social class was measured by Hollingshead's Two-Factor Index which measures 5 levels of social class. This index is based on education and occupation and has a reliability of .906 (Hollingshead and Redlich, 1958). For this study Class I will be defined as upper class, Classes II and III as middle class, and Classes IV and V as lower class (Kessler and Cleary, 1980).

In addition to examining the effect of social class on father custody, 4 other variables were included in the analysis: religion, the attitude of the ex-wife toward the father at the time of the divorce, whether or not the ex-wife supported the relationship with his children and the attitudes of the father's present wife. Of these, only religion, measured as Protestant or Catholic, appeared to have an effect on father custody.

The sample was 96% white, 60% Protestant, and well educated. Only 22% had a high school education or less, 41% had some amount of college, 21% were college graduates, and 14% had graduate degrees. Nine percent were in the Upper Class I, 79% in the middle Classes II and III, and 11% in the lower Classes IV and V. There was no statistically significant relationship between religion and social class.

The Chi-Square Test of Independence was used to test the hypotheses, correcting for cells less than 5. Cramer's V was used to measure the strength of the association. Alpha was set at .05. Because the sample is obviously neither random nor representative, generalizations cannot be made to the population of divorced fathers at large. The use of statistical tests is not intended to estimate population parameters, but to test hypotheses and establish the location of individuals in relationship to others (Farber, 1957; Coleman, 1961; Zelditch, 1961; Lee, 1977).

RESULTS—Of the 98 respondents answering this question, 19 had obtained custody of 1 or more of their children (Table 1.) Custody was held by 73.6% of middle-class fathers compared with only 26.4% of lower-class fathers. No upper-class fathers held custody. These findings were statistically significant. The null hypotheses of no difference is rejected when father custody is used to indicate a rejection of traditional parental roles. Middle-class families are more likely than upper-class or lower-class families to reject traditional custody roles.

Religion was the only 1 of the 5 potential intervening variables which showed a possible influence on custody arrangements. Custody was held by 87.5% (14) of Protestants compared with only 12.5% (2) of Catholics. These differences were not statistically significant.

TABLE 1. Number of fathers having custody of 1 or more of their children by social class.

	Social Class											
	I		II		III		IV		V		Totals	
Custody of Child	%	N	%	N	%	N	%	N	%	N	%	N
Yes		0	(36.8)	7	(36.8)	7	(26.4)	5		0	(100.0)	19
No	(11.3)	9	(30.0)	24	(51.3)	41	(6.3)	5	(1.1)	1	(100.0)	80

$X^2 = 9.38$, d.f. = 4 ($P < .05$).
Cramer's V = .31.

DISCUSSION—Merton's theory of social structure and anomie has been used as an alternative to economic determinism to provide an explanation for changes in family structure. The results suggest that changes in class values have an impact upon family structure and parental roles. The evidence presented is based on a limited sample which cannot be generalized, and the association between father custody and social class is weak. As an exploration, however, it warrants further investigation into the systemic relationship between family structure, other institutional arrangements and cultural values as suggested by Goode (1963).

The finding that Catholics were less likely than Protestants to defy tradition and to assume father custody is strongly supported by Durkheim's (1951) finding that Catholics possess a higher degree of integration with group norms. External validity is provided by other findings and impressionistic events. Gersick (1979) observes that fatherhood, which had become an increasingly amorphous position since the industrial revolution, seems to be enjoying a resurgence while the role limitations imposed by motherhood are being questioned. Increases in leisure time, disenchantment with material wealth as a measure of happiness, and the espousal of closer relationships have led men to seek greater involvement in family life. At the same time, women are finding the demands of single parenthood taxing and incompatible with marketplace demands. I would further suggest that these phenomena are centered in the middle class. Involvement in human potential classes, personal growth groups, and similar manifestations of the mental health movement seems to be evident in the more verbal upper middle-class segment of the population. The women's liberation movement has also appealed to, and obtained leadership from, the middle class (Duberman, 1974).

Gersick's (1979) study compared 20 men who had received custody with 20 who had not. Higher educational and occupational levels were found among the 20 fathers who had custody ($t = 1.7$, $p < .10$). He did not find any differences attributed to religion between the 2 samples. His findings also indicate that the reassignment of traditional parental roles may be a family decision. In 10 of the 20 cases of father custody, the decision was mutually derived prior to the court hearing. While in some of these cases unfaithful wives may have acquiesced to avoid public humiliation, in other cases the wives did not want custody or felt the fathers could offer a more secure home life (number not specified). In 7 cases, the children's decision regarding custody was accepted by the parents. The acceptance of father custody by the family group and across generational lines suggests that the assumption of cultural change indicated earlier is not unwarranted.

The meaning of this interest in father custody and whether or not it constitutes a rebellion against institutional means and ends warrants further consideration. Not only has the percentage of fathers obtaining custody remained constant, but also many more men talk about having their children live with them after divorce than those who follow through the legal process (Pearson, et al., 1982). Men may also assume custody involuntarily when the mother abandons her role. On the other hand, father custody not only represents a reversal of parental roles, but it also threatens the instrumental functioning of the father. The full-time assumption of nurturing responsibilities can lead to conflicts which threaten career advancement or even job retention. Freedom to engage in leisure activities and the type of activities pursued are also likely to be affected by the increase in nurturing tasks. The changes in life style engendered by assuming father custody argue for the interpretation of father custody as a rejection of arbitrary definitions of parental roles.

That father custody indicates a rejection of cultural ideals regarding the role of the family is more problematic. While a few liberationist groups have openly advocated the abolition of marital and familial roles (Duberman, 1974), there is no evidence that this approach has appealed to middle-class parents. Evidence of recent changes in the values attached to family life is numerous. Increases in the number of mothers in the labor market have been accompanied by demands on economic institutions for increased day-care services and flexible working hours. Reports of greater marital satisfactions noted by middle-aged couples in the empty nest stage have increased awareness that child rearing has its disadvantages. Delayed entry into marriage, increases in 1 or 2 child families, and postponement of child bearing indicate that the structure of family life is being reevaluated by at least some elements in our society.

This study has only touched on 1 manifestation of change in familial structure. Father custody represents a more drastic change in existing norms than other custody alternatives such as joint custody or shared-parenting. These alternatives seem to point toward changes in familial structure which do not call for a rejection of the traditional goals of nurturance within a two-parent context.

Merton's paradigm of social structure and anomie has provided a useful theoretical scheme for examining changes in family life. It emphasizes the role of class structure as an independent variable effecting family structures.

It also demonstrates the interactive effect of familial change on other institutional arrangements.

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DROUGHT IN SOUTHEASTERN UNITED STATES

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Abstract: *Eigenvector analysis of Palmer Drought Index values for southeastern United States for 1931-79 reveals that the 1930s and 1950s experienced the most significant droughts. Generally, the dry conditions in the Southeast were less severe than those of the Midwest at the same time. The 1971-79 period was significantly wetter than normal in nearly all of the Southeast. Moisture conditions in south-central and southern Florida are generally out of phase with the remainder of southeastern United States.*

Hounam et al. (1975) stated that drought may start any time, last indefinitely and have a wide range of severity. These vagaries of drought, coupled with the fact that drought is the third most costly geophysical phenomenon (Haas, 1978), have given the impetus for many states to initiate drought-related studies. Much of this attention, including the recent $1 million United States federal government program to help semi-arid states develop drought-mitigating weather modification techniques, has been directed toward the western portion of the country. The Northeast has also been the focus of many drought studies (e.g., Namias, 1966; 1967).

The Southeast has received relatively less attention, despite the fact that drought has been a significant, if not dominant meteorological factor in this portion of the country in recent years. Wagner (1982) indicated that the largest dry area relative to normal in the country during 1981 was the Southeast, with some regions, notably southern Georgia and northern Florida receiving less than 60% of normal annual precipitation. More drought studies relating to this part of the country are needed so that appropriate responses to drought and potential cloud seeding strategies can be developed. We discuss the basic spatial-temporal patterns of drought in the Southeast since 1931, and compare the results with Klugman's (1978) analysis of moisture conditions in the upper Midwest for 1931-69.

Data and Methods—Palmer Drought Index (PDI) values were acquired from the National Climatic Center (NCC) for each month in the 1931-79 period for the 53 climatic divisions in the 7 southeastern states of Florida, Georgia, Mississippi, Alabama, Tennessee, South Carolina and North Carolina. Data were obtained through 1979, which was the most recent year for which final monthly PDI values were available from the NCC at the time of this analysis. The study period was divided into 4 10-year periods and a final 9-year period. The 120 mo of data for each of the first 4 decades were arranged into 53 × 120 matrices; data for 1971-79 were put into a 53 × 108 matrix.

Although Shear and Steila (1973) noted that occasionally the PDI incorrectly categorizes the moisture status of some climatic divisions in the southeastern part of the country, the PDI has proven to be a generally stable and reliable indicator of dry-wet conditions over a wide range of climates in the United States (Felch, 1978). It is used here to provide comparability with previous studies of other portions of the country employing the PDI. The Index has been succinctly described by Stockton and Meko (1975) and Karl and Quayle (1981).

The basic spatial-temporal patterns of drought for the 5 time periods and 53 climatic divisions were determined using eigenvector analysis of the PDI data. The eigenvector technique allows the variability of a data field to be largely accounted for by a relatively few uncorrelated components, and yields the characteristic patterns in large data sets. Recent general discussions and examples of this common technique have been given by Skaggs (1975), Johnson (1980), Hayden (1981) and Rogers (1981). Normalized eigenvectors were extracted from cross products matrices of unnormalized PDI values for each period using the technique in Helwig and Council (1979). Although this type of input matrix has not been extensively used in meteorological research, it is employed here to maintain comparability with Klugman. The procedure was done such that the eigenvectors represented variance-maximizing spatial patterns of drought. Each element in an eigenvector represents one climatic division. These are mapped to reveal the basic geographic distribution of drought in the Southeast. Corresponding coefficients are functions of time, which are plotted as a monthly time series to indicate how well the associated eigenvector pattern resembles actual dry-wet conditions.

RESULTS—Table 1 shows the explained variance incorporated in the first 3 eigenvectors for each time period. The technique of Stidd (1967) was used to choose the number of eigenvector patterns to analyze; this resulted in the retention of 3 eigenvectors for each period. The explained variance of eigenvector 3 for each period corresponds closely to Skaggs' (1975) lowest-bound value of 7.0%.

TABLE 1. Percentage of total variance explained by the first 3 eigenvectors.

	Eigenvector			
Years	1	2	3	Total
1931-40	32.2	17.4	11.2	60.8
1941-50	41.6	20.4	9.4	71.4
1951-60	51.4	15.1	7.0	73.5
1961-70	43.7	16.3	9.1	69.1
1971-79	74.7	6.0	5.1	85.8

1931-40: Figure 1a and 1b reveal the most significant regional anomalies in moisture conditions for the 1930s. All values are negative in the first eigenvector pattern (Fig. 1b) except in extreme southern Florida. This fact, coupled with the predominance of positive values of the coefficients of eigenvector 1 (Fig. 1a), indicates generally drier than normal conditions for most of the Southeast in that decade. Departures from normal were generally greatest in South Carolina, where eigenvector values ranged to −0.20. The monthly importance of the eigenvector 1 pattern is revealed by Fig. 1a. This shows that the first eigenvector pattern fits actual moisture conditions particularly well on 6 occasions (where the coefficients exceed an absolute value of 10.0). The graph shows that late 1931, most of 1933, and early 1934 were particularly dry. The significant negative values, especially in late 1932, indicate that the inverse of Fig. 1b explains the moisture conditions for those periods; e.g., generally wet conditions prevailed. The first eigenvector reveals a rather cyclic pattern of moisture conditions for the decade. Moderate to severe drought in much of the Southeast in late 1931 changed to very wet conditions in late 1932, followed 1 yr later by one of the driest periods of the decade. The years from 1935-40 showed less dramatic changes than the early part of the decade.

Eigenvector 2 (Fig. 2a), which represents deviations from eigenvector 1 and thus reveals more local patterns of moisture, shows negative values in the eastern portion of the study area and positive ones in the west. Absolute values are greatest in central Florida and northern Mississippi. This pattern was significant in the late 1931-early 1932 and mid 1935 (Fig. 1a). Both times the time-series coefficients are positive, showing the stronger dry conditions in the east than in the west. Peninsular Florida experienced severe drought conditions at both of these times, as did eastern Georgia and South Carolina, whereas northern Mississippi and other areas in the western half of the study area received well above normal precipitation at these 2 periods.

The pattern of eigenvector 3 (Fig. 2b), which represents progressively more local conditions than eigenvector 2 and is less important in terms of explained variance, shows negative values in the southern and eastern areas. The associated coefficients exceed 10.0 only for a brief period in early 1936. At this time some minor dryness was experienced in Florida and Mississippi, while in parts of North Carolina extremely wet conditions locally prevailed for a few months.

1941-50: The generally dry conditions of the 1930s continued through 1944. Eigenvector 1 of the 1940s (Fig. 3b), as with eigenvector 1 of the previous decade, reveals all negative values except in southern Florida. The dry conditions were briefly interrupted with widespread moist conditions in early 1944, as revealed by the large negative coefficients in Fig. 3a at that time. The wet conditions abated for approximately 14 months, then dominated through the end of the decade over most of the Southeast.

The second eigenvector (Fig. 4a) is relatively important in this decade, accounting for approximately one-fifth of the variance (Table 1). It reveals some local variations from the general pattern of eigenvector 1. In a few regions, particularly in the southern portions of Georgia, South Carolina and Florida, relatively wet conditions occurred in early 1942 while the remainder of the Southeast was experiencing the continuation of the periodic droughts from the 1930s. In contrast, some areas north of the zero-value isoline, especially Tennessee, experienced dry conditions during the generally wet 1947-48 period.

The spatial distribution of eigenvector 3 (Fig. 4b) is quite complex and important only during mid 1942 through mid 1943. That this pattern was particularly important for this 12-month period is revealed in Fig. 3a, which shows that the coefficients for eigenvectors 1 and 2 at this time are very near zero. Some respite from the early 1940s dryness occurred at this time in those areas where the eigenvector values in Fig. 2d are near -0.20.

1951-60: As revealed by Figs. 5a and 5b, the early 1950s through mid 1957 showed a return to dry conditions. All eigenvector 1 values are negative, and the corresponding coefficients exceed an absolute value of 10.00 in every year except 1953. In late 1954, with the coefficients of eigenvector 1 exceeding 25.0, 46 of the 53 climatic divisions experienced severe or extreme drought conditions. However, nearly equally anomalous wet conditions

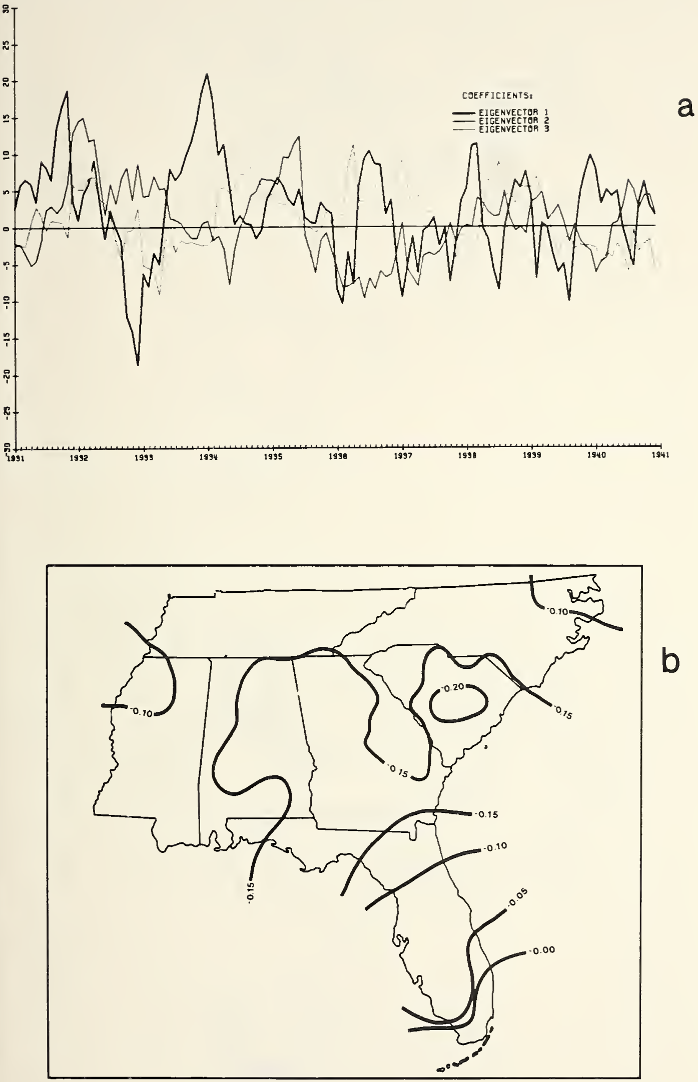

FIG. 1. Coefficients of the first 3 eigenvectors (a), and map of eigenvector 1 (b), 1931-40.

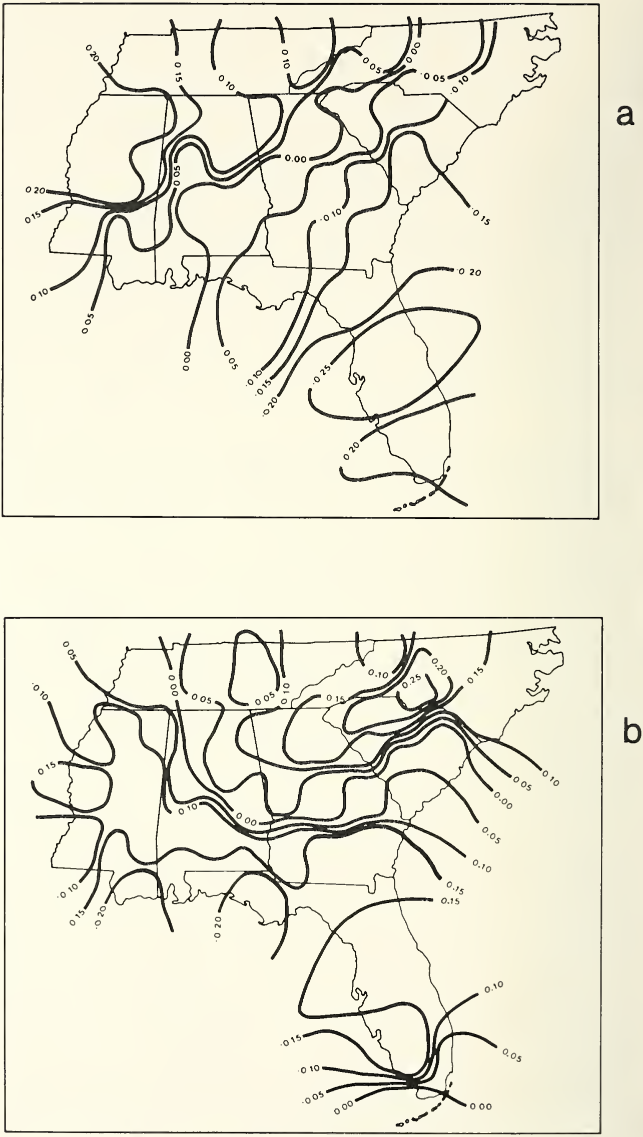

Fig. 2. Maps of eigenvector 2 (a) and eigenvector 3 (b), 1931-40.

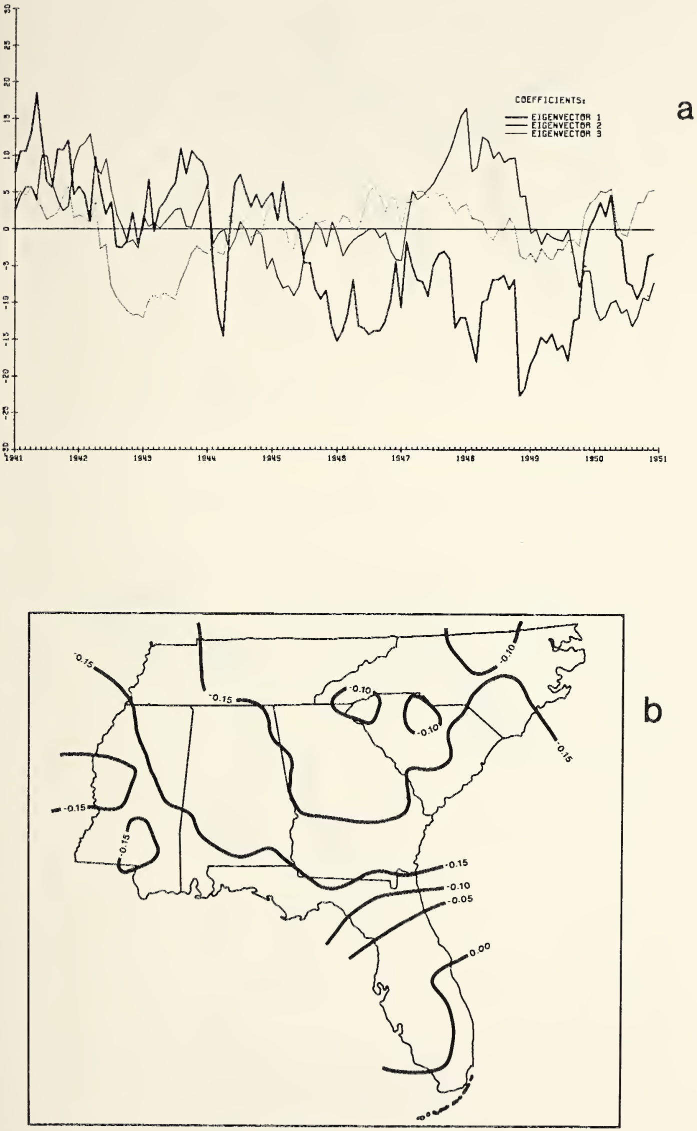

Fig. 3. As in Fig. 1 except 1941-50.

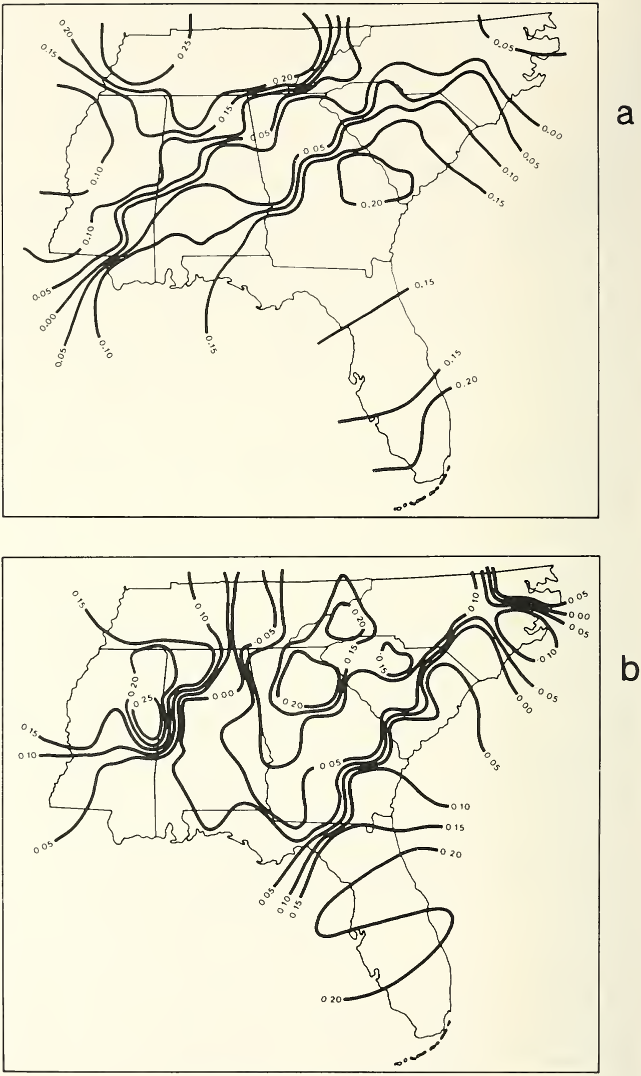

Fig. 4. As in Fig. 2 except 1941-50.

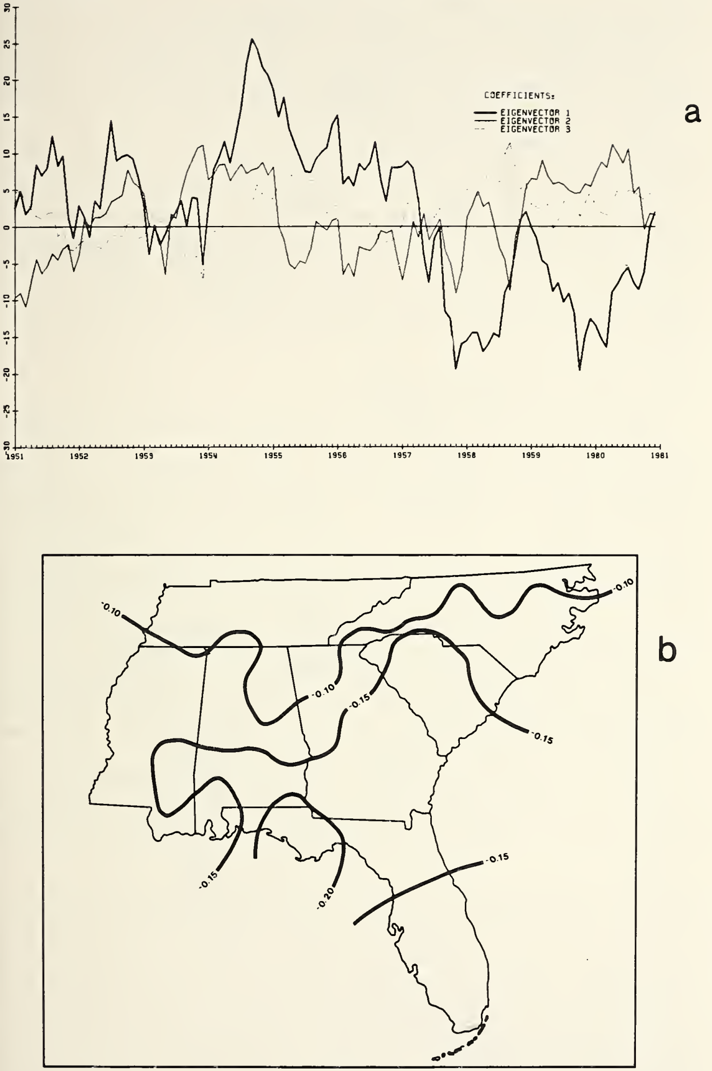

FIG. 5. As in Fig. 1 except 1951-60.

dominated most of the last few years of the 1950s. For example, the Florida panhandle, which displays the most significant eigenvector 1 values (−0.20), changed from 23 consecutive months of severe drought during the mid 1954-mid 1956 period to severe wet conditions in mid 1957 to mid 1958 and for 12 mo beginning in the middle of 1959.

Figure 6a shows that eigenvector 2 values are most significant in Tennessee and central Florida. The pattern was important in early 1951, late 1953 and early 1960 (Fig. 5a). This indicates that the dryness or near normal conditions over much of the Southeast during early 1951 were absent in Tennessee, which experienced extremely wet conditions in the first few months of that year. Another anomaly revealed in the pattern of this eigenvector is the extremely wet period in central Florida during the last few months of 1953, when the remainder of the Southeast generally experienced normal or slightly dry conditions.

The pattern of eigenvector 3 shows a few very localized anomalous conditions in mid 1958 (Figs. 5a and 6b).

1961-70: Much of the 1960s decade was wetter than normal throughout most of the Southeast. This is shown by the negative eigenvector 1 values in all areas except southern Florida (Fig. 7b), coupled with the preponderance of negative values of the coefficients of eigenvector 1 in Fig. 7a, indicating that the inverse of the eigenvector 1 pattern is the best representation of moisture conditions for every year in the 1961-70 period. The 1964-6 period was particularly continuously wet in South Carolina, northern Georgia and eastern Mississippi. Again, central and southern Florida were out of phase with the rest of the Southeast, often experiencing extended negative departures from normal rainfall throughout much of the decade.

The pattern of the second eigenvector (Fig. 8a) accentuates the anomalous conditions of north-central Florida: relatively dry months occurred at the end of 1961 in this part of Florida when most of the Southeast was experiencing normal to wet, sometimes extremely wet, conditions.

Eigenvector 3 was significant during the middle portion of 1963 (Figs. 7a and 8b). It indicates that a few climatic divisions in southeastern Mississippi and southwestern Alabama were significantly below normal in rainfall at that time.

1971-79: Most of this period was wetter than normal. The pattern of eigenvector 1 (Fig. 9b) is very similar to the distribution of the first eigenvector values of the 1960s, with negative values in all regions except central and southern Florida. Figure 9a shows that this pattern, which accounts for 74.7% of the variance, was dominant in all years of the period except portions of 1977 and 1978. Regions of greatest anomalies are in the central portions of Mississippi, Alabama and Tennessee. These areas experienced 4 consecutive years of extremely wet conditions from 1973-76. Normal rainfall amounts returned to these areas and most of the Southeast during 1977 and 1978, but again in 1979 very wet conditions prevailed, especially in the last few months of the year (Fig. 9a). In southern Florida, with the only positive

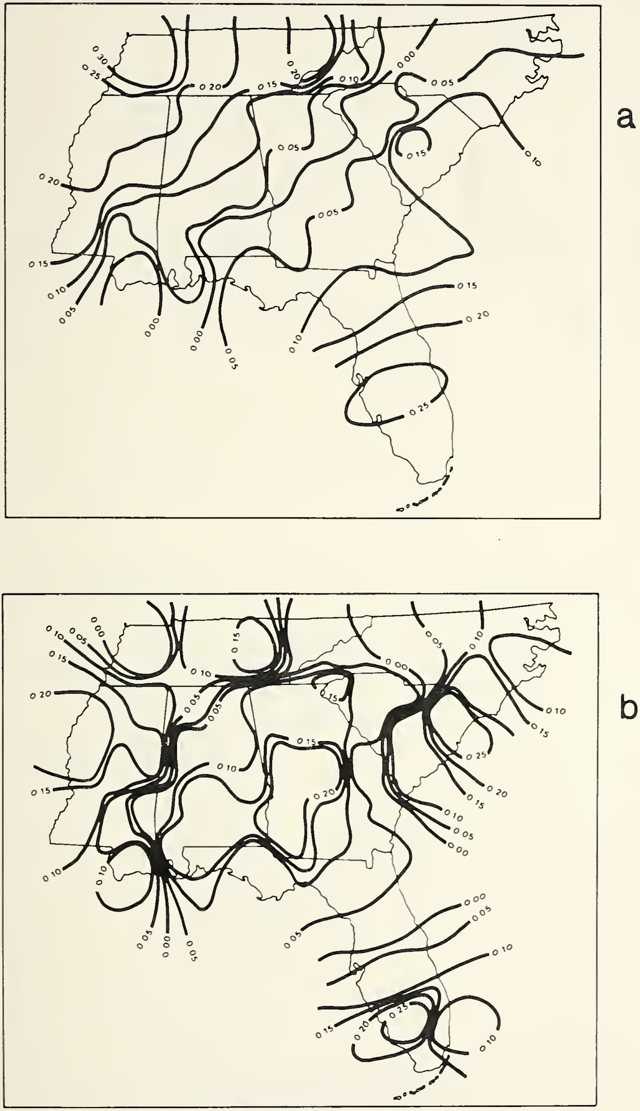

Fig. 6. As in Fig. 2 except 1951-60.

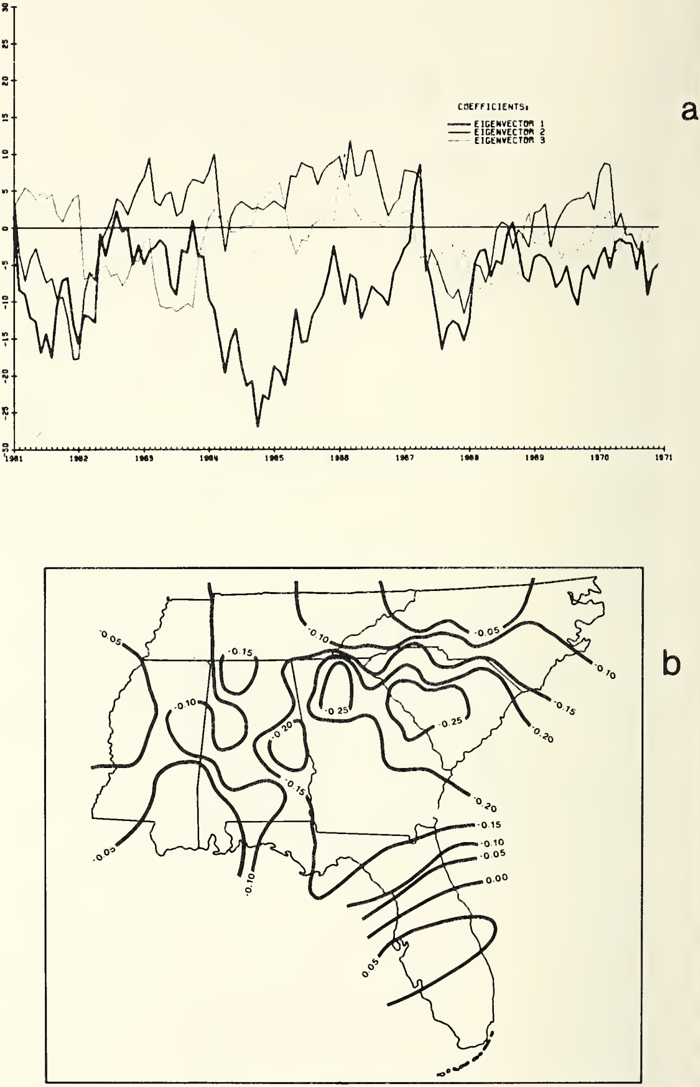

Fig. 7. As in Fig. 1 except 1961-70.

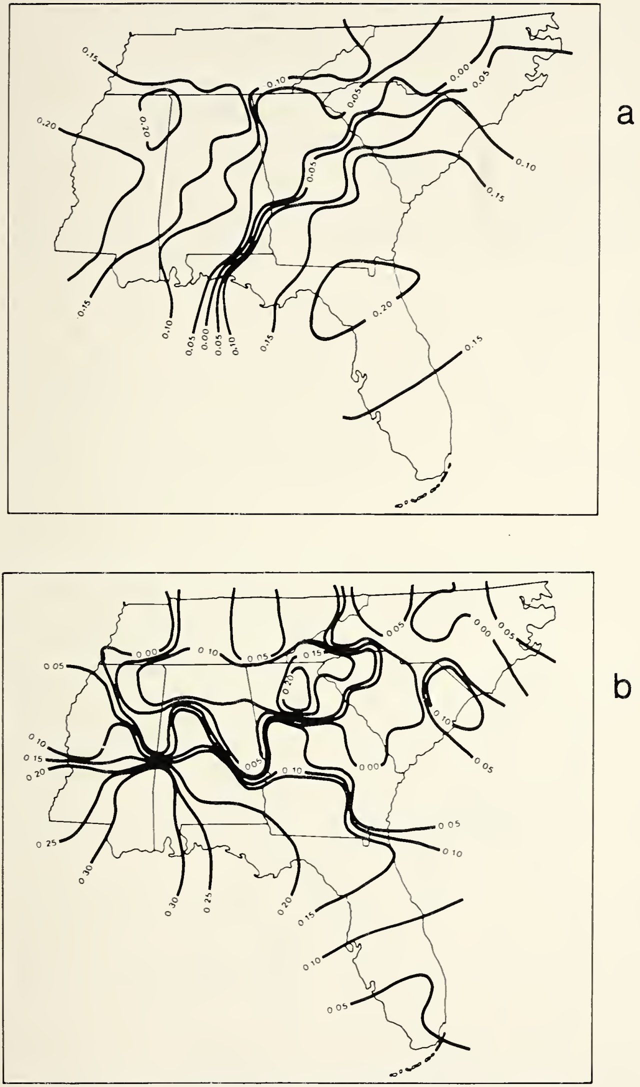

Fig. 8. As in Fig. 2 except 1961-70.

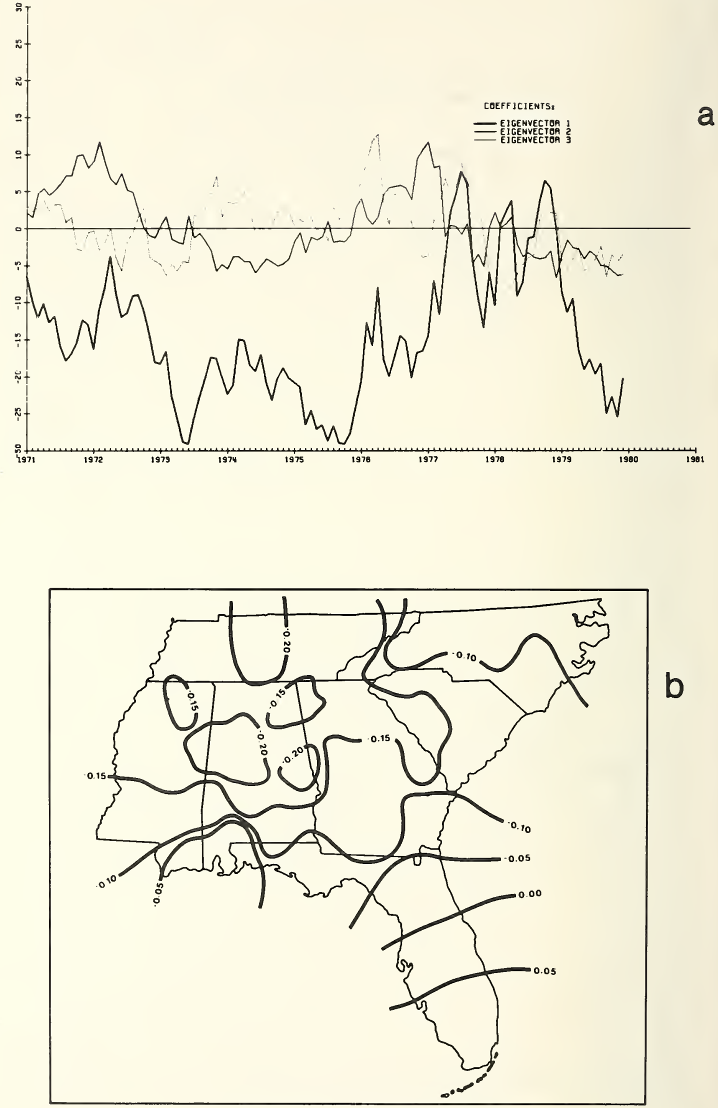

FIG. 9. As in Fig. 1 except 1971-79.

values in Fig. 9b, moisture conditions were the reverse from the rest of the Southeast: dry for most of the period, particularly in the Keys climatic division in extreme southern Florida, which experienced severe drought for a 19-mo period centered around the entire year of 1975. The last 4 mo of the 1970s were equally dry in the area.

Eigenvectors 2 and 3, which together account for 11.1% of the total variance, are shown in Figs 10a and 10b. They are important for only a few months in the 1970s, but the patterns further substantiate the wet conditions, indicate a minor dry period in northern and western Mississippi in the late 1971-early 1972 period, and highlight the unique moisture regime of central and southern Florida.

Discussion and Summary—Eigenvector analysis of Palmer Drought Index values in southeastern United States for the 1931-79 period reveals significant variation of drought conditions geographically and over time. The overall pattern, which is revealed by the pattern of eigenvector 1 and the corresponding coefficients for each time period, shows 1) generally drier conditions than normal for much of the 1930s, with the driest periods occurring roughly 2 years apart; 2) a continuation of dryness for the first few years of the next decade, with a gradual change to wetter conditions in the last few years; 3) a return to dry conditions in the 1950-57 period, with a significant prolonged drought from 1954 into 1956, followed by a wet-normal-wet sequence at the end of the decade; 4) generally normal to wet conditions throughout the 1960s, with significant drought occurring only in central and southern Florida; and 5) continuation of widespread wet conditions in all years of the 1970s except 1977-78, with central and southern Florida again out of phase with the remainder of the Southeast.

The basic decade-average moisture conditions in the Southeast were similar in many respects to those of the upper Midwest as revealed by Klugman's (1978) eigenvector analysis of that region for 1931-69. However, several differences are apparent. The very severe drought in the midwest in 1933-4 and 1936, although present, was less severe in the Southeast. This is also true of the drought of the mid 1950s; nearly every climatic division in the Southeast experienced some severe drought in the 1954-5 period, but it was not as pronounced or prolonged as that in the upper Midwest at that time.

Although detailed discussion of the causes of droughts is beyond the scope of this note, a recent paper by Douglas and Englehart (1981) particularly applies to the study area. They found a statistical relationship (correlation of 0.69) between autumn rainfall in the central equatorial Pacific and subsequent winter precipitation in south-central Florida. Suggested teleconnection mechanisms involve large-scale circulation changes associated with warming in eastern tropical Pacific sea surface temperatures, which influence frontal activity and possibly cyclogenesis in the Gulf of Mexico. Warm, dry winters in central Florida were favored by weak troughs in

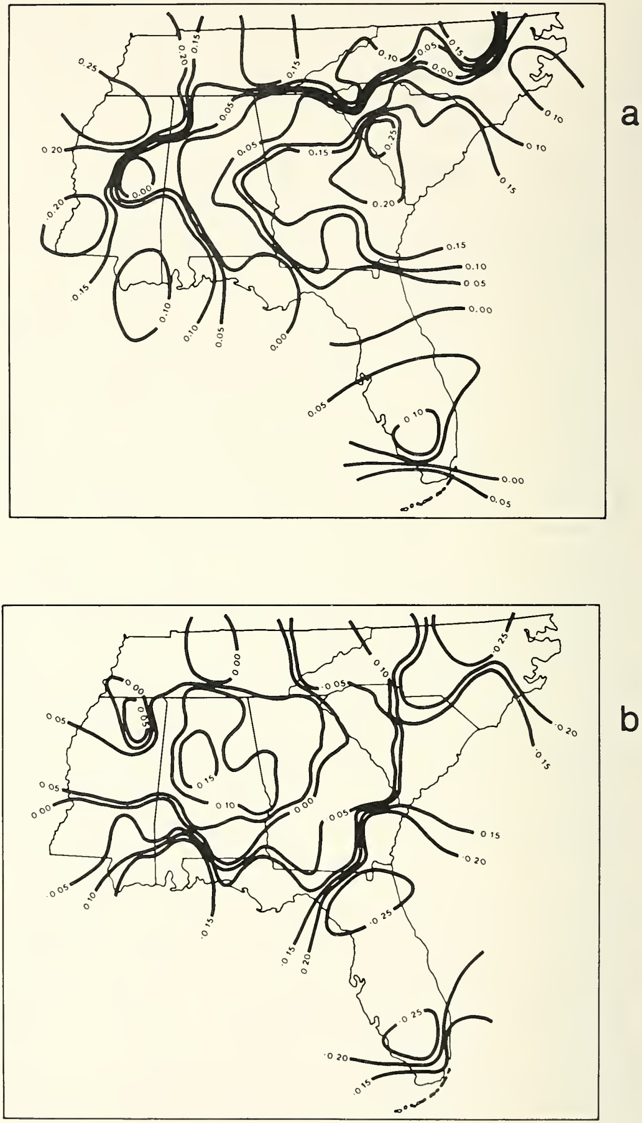

Fig. 10. As in Fig. 2 except 1971-79.

700-mb fields in eastern United States, with coincident decreased storm activity in the Gulf of Mexico. The strong correlation exists, however, only in south-central Florida. Correlations for other sections of the Southeast are lower and become negative toward the north. These findings corroborate those in the present analysis which show that the moisture status in central and southern Florida is generally out of phase with the remainder of the southeastern United States.

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SPECIES COMPOSITION AND RELATIVE ABUNDANCE OF ATTACHED DIATOMS AND OTHER ALGAE IN THE COASTAL WATERS ADJACENT TO SEAHORSE KEY, FLORIDA*

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Abstract: *Five collections of attached diatoms and other algae obtained during warm and cold seasons yielded 111 species. Seventy-nine percent were diatoms, the rest blue-green, green, red, and brown algae. During the warmer months, most species occurred on leaves of 3 seagrasses: the least number was on smooth cordgrass* (Spartina alterniflora) *stems, mangrove* (Avicennia germinans) *pneumatophores and oyster shells. During most of the coldest months, a reversal of this distribution was observed which was attributed to disappearance of most seagrass leaves during the winter.*

Although macroalgae and planktonic marine algae of the south and west coasts of Florida and the Gulf of Mexico have been the subject of many studies (El-Sayed et al. 1972; Jones et al. 1973; Zimmerman and Livingston, 1979), attached algae, particularly the diatoms, have received less attention (Sullivan, 1979). Except for the reports of Reyes-Vasquez (1970) and Miller et al. (1977) concerned with diatoms epiphytic on *Thalassia testudinum*, the epiphytic and epipelic diatom study of the upper Florida Bay by DeFelice and Lynts (1978) and the preliminary study of Sullivan (1979), we know of no other field studies concerned with the attached marine diatoms of Florida or the Gulf of Mexico. We report on species composition and relative abundance of diatoms and other algae scraped from leaves of seagrasses, smooth cordgrass stems, black mangrove pneumatophores and oyster shells in the water adjacent to Seahorse Key, Florida.

Material and methods—Seahorse Key (Lat. 29° 11′ N and Long. 83° 00′ W) is an island approximately 4.8 km southeast from the small town of Cedar Key off the Gulf Coast of Florida. The coastline in this area is subject to slight wave action (Tanner, 1960; Strawn, 1961) and water quality is influenced strongly by outflow from the mouth of the nearby Suwannee River. The 7 study sites (Fig. 1 and Table 1) were delineated as grid systems or line transects. Sites 1 and 1A were composed primarily of *Thalassia testudinum* König and *Syringodium filiforme* Kütz. Site 2 designated "shallow *Thalassia*," was dominated by *T. testudinum*. Site 3 supported a nearly pure stand of *Diplanthera wrightii* Aschers. (= *Halodule wrightii* Aschers.). This site escaped excessive desiccation when the tide receded because the leaves were always flat against the wet sediments. Site 4 was an oyster reef (*Crassostrea virginica* L.) which became apparently dry when exposed at low tide with temperatures presumably identical to the atmosphere. Site 5 supported a pure stand of smooth cordgrass–*Spartina alterniflora* Loisel. This site was also exposed during low tides, but the stem portion of *S. alterniflora* which was sampled remained damp. The pneumatophores of *Avicennia germinans* (L.) Stearn at Site 6 were under water at high tide, but quickly dried when exposed to air. The 3 seagrasses were designated as "wet" substrates, *S. alterniflora* as a "damp" substrate, and the others as "dry" substrates.

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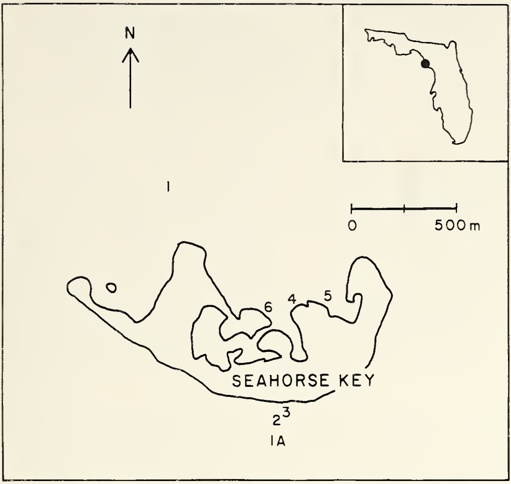

FIG. 1. Collecting sites (numbers) adjacent to Seahorse Key, Florida.

TABLE 1. Substrate identity, water depth at mean high tide, and relative frequency of exposure at the study sites.

Substrate	Site	Wet, Damp, or Dry	m Below Mean High Tide	Relative Frequency of Exposure At Low Tide
Thalassia testudinum and *Syringodium filiforme*	1,1A	Wet	1.75	Never
Shallow *Thalassia testudinum*	2	Wet	1	Occasional
Diplanthera wrightii	3	Wet	<1	Almost Always
Crassostrea virginica shells	4	Dry	0.5	Always
Spartina alterniflora stems	5	Damp	0.7	Always
Avicennia germinans pneumatophores	6	Dry	0.5	Always

Samples were collected during the following periods: 9-10 August 1975, 27-29 September 1975, 21-24 November 1975, 3-4 January 1976, and 3-6 March 1976. Substrates at each sampling site were harvested within a 0.15 m^2 quadrat and their surface areas measured. The epiphyton was scraped from the ends, centers, and lowermost portions of representative seagrass blades, mangrove pneumatophores, and the portions of the smooth cordgrass stems from immediately above the sediment–water interface to the area where no further algal growth was apparent. Attached algae on oysters were scraped from 1 cm^2 of representative shells located on the crest of the reef.

Every sample of detached algae from each substrate was suspended in flasks, subsamples placed in a Palmer or Sedgwick Rafter counting chamber, and counted with a compound microscope to obtain relative abundance values of each species. Values obtained for the nondiatom algae were averaged over the entire surface of the harvested substrates. One thousand diatom frustules were counted from each sample in a Palmer counting chamber. Diatom frustules were cleaned in a H_2O_2 solution with a small amount of $K_2Cr_2O_7$. The cleaned frustules were mounted in "permount" (Fisher Scientific Co.) on glass slides and identified. Except for the calcareous red alga *Fosliella atlantica* (Foslie) Taylor, multicellular algae were quantified in a Sedgwick Rafter chamber by measuring total length in terms of square measuring grid units with the method recommended by Olson (1949). *Fosliella atlantica* thalli and unicellular blue-green algae were counted in 3 to 6 volumes of a Palmer chamber. For each substrate and collection, relative abundance values of each species are in Table 2 as rare (1-10), common (11-99), or abundant (100 and greater).

RESULTS—Salinity measured at high tide with an electrical conductivity meter (Beckman RB3 Solu Bridge) remained almost constant at 32 ‰ for each of the 5 collecting periods. Water temperatures recorded at high tide of each collecting period with a mercury-in-glass thermometer varied from a summer high of 30.5^{C} to a winter low of 14.0^{C}. Light extinction, determined with a Secchi disk in the adjacent main ship channel, ranged from 0.8m in August to 0.5m in March. In this channel, water colors were frequently yellow-brown, with much suspended material evident. The mean tidal range in the Cedar Key area during the study period was 0.8m; however, strong winds often caused tides to exceed this range.

Proportions of seagrass leaf surface area to unit area of the underlying sediments were highest in August and gradually diminished to a minimum March (Fig. 2). Surface area ratios for the pneumatophores, oyster shells, and smooth cordgrass stems remained unchanged throughout the study period. Most seagrasses became defoliated and died back to the rhizomes during the colder months.

The 111 species identified consisted of 88 diatom species, 10 red algal species, 7 blue-green algal species, 4 green algal species, and 2 brown algal species (Table 2). Most organisms were physically attached by a holdfast or substance of their own secretion. Others are more properly regarded as members of the planktonic community (e. g., *Coscinodiscus* and *Cyclotella*) and were entangled with the attached algae or portions of the substrates.

Diatoms and blue-green algae were the most abundant forms found on all 7 substrates. The most ubiquitous diatom species were (in order of decreasing relative abundance): *Synedra affinis*, *Nitzschia closterium*, *Navicula cancellata*, *Cocconeis* cf. *dirupta*, *Achnanthes longipes*, *Synedra* cf. *nana*, *Cyclotella striata*, *Grammatophora marina*, *Navicula longa*, *Nitzschia longissima*, *Navicula* cf. *paucivisitata* and *Coscinodiscus radiatus*. The most abundant blue-green algae were *Microcoleus lyngbyaceus*, *Oscillatoria*

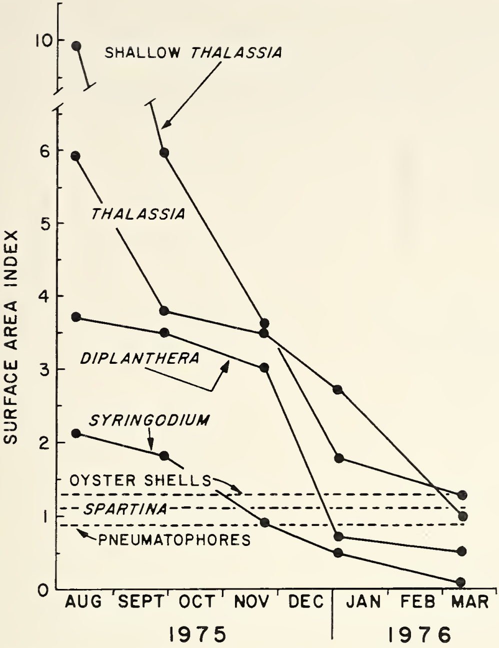

FIG. 2. Surface area index of each substrate during study period. The *Thalassia* and *Syringodium* plots are composites of sites 1 and 1A.

submembranacea, and *Schizothrix mexicana*. The encrusting red algae *Fosliella atlantica* and *Acrochaetium sargassi* were also prominent during collection dates on the seagrass substrates. *Polysiphonia denudata* was found primarily on pneumatophores in the September collection. *Ectocarpus siliculosus*, collected only in January from the substrates always exposed at low tides (sites 4-6), formed a conspicuous fringe at the low water mark that was especially striking on the oyster reefs.

Table 3 lists the total number of species present during each collection for each substrate. The August collection displayed the greatest number of species and January the least. Most species among substrates were found on *Thalassia* (from the deeper sites) and *Avicennia* pneumatophores, and the least on the oyster shells.

DISCUSSION — The data herein reported constitute a first record for the abundance and occurrence of diatoms attached to leaves of 3 seagrass species and other substrates in the Cedar Keys area.

For nondiatom epiphytes, Humm (1964) observed that abundance and

TABLE 2. Algal species and their relative abundance on seven substrates around Seahorse Key, Florida from August 1975 to March 1976. The following code is used. A = abundant (100 and greater, C = common (10-99), R = rare (1-9), blank = absent. The designations for *Thalassia* and *Syringodium* are composites of sites 1 and 1A.

SPECIES	*Thalassia*					*Syringodium*				
BACILLIARIOPHYCEAE	A	S	N	J	M	A	S	N	J	M
Achnanthes longipes Agardh	R	C	R	C	C	R	C	R	R	
Actinoptychus senarius (Ehrenberg) Ehrenberg										
Amphiprora alata (Ehrenberg) Kützing	R	R				R	R	R		
Amphora bigibba Grunow	R									
A. decussata Grunow	R	R								
A. marina Van Heurck	C	C	C	R	R	R	R	R	R	
A. obtusa Gregory	C	C	C		R	C	C	C	C	
A. spectabilis Gregory										
Asterionella glacialis Castracane		R								
Auliscus punctatus Bailey	R	R	R	R	R	R	R			
Bacillaria paxillifer (O.F. Müller) Hendey	A	C	C			A	C	R		
Bellerochea malleus (Brightwell) Van Heurck		R	R	R	R	R		R		
Biddulphia mobiliensis (Bailey) Grunow					R					
B. rhombus (Ehrenberg) W. Smith										
B. sculptum (Shadbolt) Van Heurck										
Chaetoceros gracile Schütt							R			
Cocconeis cf. *dirupta* Gregory	C	C	A	A	C	R	C	C	C	C
C. disculoides Hustedt	R	R	C	C	R	R	C	C	A	C
C. scutellum Ehrenberg	R	R	R		C	R	R			C
C. sp.	R	R				R	R			
Coscinodiscus centralis Ehrenberg	R	C	R	C	R		C	R	R	R
C. radiatus Ehrenberg	C	C	C	C	C	C	R	R	C	
Cyclotella striata (Kützing) Grunow	C	C	C	R	C	R	R	R	R	R
Cymatosira belgica Grunow	R				R					
C. lorenziana Grunow	R								R	
Dimeregramma minor (Gregory) Ralfs										
Diploneis crabro Ehrenberg			R	R		R		R		
D. smithii (de Brébisson) Cleve						R				
Eunotogramma laeve Grunow	R			R		R				R
Fragilaria inflata Pantocsek		R								
Grammatophora marina (Lyngbye) Kützing	C	C	R	C	C	A	A	C	R	
Gyrosigma balticum (Ehrenberg) Rabenhorst	R	R	R	R		R	R			
Licmophora abbreviata Agardh	C	C	C	C	C	C	A	C	A	A
L. flabellata (Carmichael) Agardh	R	R	R		C	C	C	R		C
L. cf. remulus Grunow	C	R	R			C	C	R		
Mastogloia cribrosa Grunow	R	R	R	R		R	R	R		
M. erythraea Grunow	C	R	R			C	R		R	R
M. exigua Lewis	C	R	R			R				R
M. lanceolata Thwaites	R	C	R	R		C	R			
M. sp.	C	C	R	C	R	C	R	C	R	
Melosira moniliformis (Müller) Agardh			R							
Navicula ambigua Ehrenberg	R					R	R	R		
N. cf. *bacillum* Ehrenberg	C	R	R	C		C	R		C	C
N. cancellata Donkin	C	C	C	A	A	C	C	C	C	A
N. cf. *latissima* Gregory		R								
N. longa Gregory	R	C	C	C	R	C	C	C	C	C
N. lyra Ehrenberg	R		R		R	R	R	R		R
N. cf. *maculata* Bailey	R		R	R		R				
N. nummularia Greville										
N. cf. *paucivisitata* Patrick	C	C	R	C	C	C	R	C	C	C
N. spectabilis Gregory	R					R	R			
Nitzschia acicularis (Kützing) W. Smith										
N. closterium (Ehrenberg) W. Smith	R	C	A	C	A	R	C	A	A	A
N. constricta Gregory	C	C	C		R	R	C	R		
N. dissipata (Kützing) Grunow	R	R	R		R	R	R			

Shallow Thalassia					*Diplanthera*					*Oyster Shells*					*Spartina Stems*					*Avicennia pneumatophores*				
A	S	N	J	M	A	S	N	J	M	A	S	N	J	M	A	S	N	J	M	A	S	N	J	M
R		R				C			C	C	A	A		C	A	A	A	C	C	C	R	A	C	C
												R												
		R						R	R			R			C	R		R			R	R	C	
																		C			R			
											R	C		R		R						C	R	C
					C	C	C	C		R	C	R	C	C	C	C	R	C	C	C	C	R	C	C
C		C	R			C	C		R		R				C	C	R		C	C	C	C	R	R
																								R
				R						C														
R		R		R	C	R	R	R		R		R	R		R	R		C		R	R	R	R	
A	C				A					C	C				C	C				C	C	R		C
		R		R				R				C	R	R	C	C		R	R		R	C	C	C
										R										R				
R			R							C			R				R				R			
		R										R			R									
C	A	C	C	A	R	A	C	C	C	R		R	C	C	C	C	C	C		C	C	C	C	C
C	R	C	C		C	C	C	A	C	R	C	C	C	R	R	C	C	A	A	C	R	C	C	C
R	R			C	C	R		C						R	R	R								
R					R															R			R	
	R	C				C	C	R	R	C	C	C	C	R	C	C	R	C	C	C	C	C	C	R
C	R	C	C	C	R	R	C	C	C	C	C	C	C	C	R	C	C	C	C	C	C	C	C	C
R		C	C	C	R	C	C	C		A	C	C	C	C	C	C	C	C	C	A	C	C	C	C
								R																
							R		R			R				R	R	R				R		R
																								R
					R		R			R	C	R		R	R	R	R			C	C	R		C
R		R	R		R		R	R	R				C	R	R							R		
															R			R		R				
C		C	C	C	C	C	C	C	R	R		R	C		C	C	C	A	R	R	C	C	C	C
R		R	C		R	R	R	R		R				R	R	R		R	C	R	C	R	R	R
C	A	C		C	C	R	R	C	C		C	R			R			C						
R	R		C	C	R				R			R	C		R	R				R		R	R	
C		R			C	R									R		R			R				R
R		R		R	R		R		R			R			R					R		R		
C						R									C	R	C			C	R	R		R
R		R			C	R								R										
C	C	R			C	C	R		R			R		R	R				C	C	C			C
R	C	R	R		R	C	C			C				C	R	C	R		C		C	C	C	R
		R								A	A	A	C	C	R	C	C			A	A	A	C	C
		R												C							R	R		
C	R				C	R				C	C			C	R	R	R		C	C	C	R	R	C
C	C	C	A	A	C	C	C	A	A	C	C	C	C	C	C	C	C	C	A	C	C	C	A	C
R									R						R	C			R	R	C		R	
C	C	C	C		C	C	C	C	C	C	C	C	C		C	C	C		C	R	C	C	C	C
R	R	R			R		R			R		R		R	C	R	C	C	C		R	R	R	C
	R		C				R	R				R	R		R	R				R	R			
																				C	C			
C	C	C	A	C	C	C	C	C	C	R	C			R	C	C		C	C	R	R	R		C
R						R										R					R			
R																								
R	A	A	A	A	R	C	C	C	A	C			C	A	R	C	C	C	A			R	C	C
C	R	C			R	C	R	C	C		C	R	C	R	C	C		C	C	R	C	C	R	
R		C	R		R		R		R			C	R	A	R	R					R	R	C	C

TABLE 2. Continued.

SPECIES	*Thalassia*					*Syringodium*				
BACILLIARIOPHYCEAE	A	S	N	J	M	A	S	N	J	M
N. cf. *fasciculata* Grunow										
N. cf. *filiformis* (W. Smith) Schütt		R	R			R	R	R		
N. longissima (de Brébisson) Ralfs	R	C	A	C	R	R	C	A	C	
N. lorenziana Grunow	R	R	R		R	R	R	R		
N. panduriformis Gregory	R	R				R				
N. sigma (Kützing) W. Smith	R	R	C	R		R	R	R		
N. tryblionella Hantzsch	A									
Opephora cf. *martyi* Héribaud	R		R					R	R	
Peronia intermedium H. L. Smith	R									
Pinnularia sp.			R							
Pleurosigma sp.	R	R	C	R	R	R	R	R	C	R
P. strigilis (W. Smith) Cleve	R	R	R	R	C	R	R	R		C
Podosira stelliger (Bailey) Mann	R	R	R	R	R	R				
Pseudonitzschia seriata (Cleve) Peragallo	R					R				
Rhabdonema adriaticum Kützing		R	R			R	R	R		
Rhizosolenia alata Brightwell	R		R				R	R		
R. setigera Brightwell	R									
R. stolterfothii Peragallo			R							
Rhoicosphenia curvata (Kützing) Grunow	R	C	R			R	C	C		
Rhopalodia gibberula (Ehrenberg) O. Müller	R					R				
R. musculus (Kützing) O. Müller	C	C	C	C	C	C	C	R	R	
Skeletonema costatum (Greville) Cleve										R
Striatella interupta (Ehrenberg) Heiberg	R	C	R			R	R			
S. unipunctata (Lyngbye) Agardh	R	R	R			R	R	R		R
Synedra affinis Kützing	C	A	C	A	C	C	A	A	C	C
S. fulgens (Greville) W. Smith	R.	R	R	R		R	R	R		
S. gaillonii (Bory) Ehrenberg	C		R			C	R			
S. cf. *nana* Meister	C	C	R	C		C	C	C		
Synedra cf. *rostrata* Pantocsek	R		R		R	R	R			
S. undulata (Bailey) Gregory		R				R				
Trachyneis aspera (Ehrenberg) Cleve	C	C	R	R	R	C	R	C		R
Triceratium favus Ehrenberg										
Surirella striatula Turpin										
CHLOROPHYCEAE										
Boodleopsis pusilla (Collins) Taylor, Joly & Bernatowicz										
Chaetomophora minima Collins & Harvey	R					C	C			
Enteromorpha compressa (Linnaeus) Greville										
E. flexuosa (Wulfen) J. Agardh						C	R			
CYANOPHYCEAE										
Agmenellum thermale (Kützing) Drouet & Daily										
Anabaena fertilissima Rao	C	C	R				R			
Calothrix sp.	R									
Coccochloris elabens Drouet & Daily	A	C								
Microcoleus lyngybaceus (Kützing) Crouan	A	C	C	C	C	A	C	C	R	C
Oscillatoria submembranacea Ardissone & Strafforello	C	C	C	R		C	C	C	C	C
Schizothrix mexicana Gomont	C	C	C	R	C	A	A	C	R	C
PHAEOPHYCEAE										
Ectocarpus siliculosus (Dillwyn) Lyngbye										
Giffordia conifera (Bϕrgesen) Taylor	C	R	R	C		C	R			
RHODOPHYCEAE										
Acrochaetium sancti-thomae Bϕrgesen					R		C		R	C
A. sargassi Bϕrgesen	C	C	A	A	A	A	C	C	A	A
Centroceras clavulatum (C. Agardh) Montagne	R		C			C	C			
Ceramium fastigiatum (Roth) Harvey								R		
Fosliella atlantica (Foslie) Taylor	A	A	A	A	A	C	A	A	A	A
Herposiphonia secunda (C. Agardh) Ambronn				R		C	R			
Polysiphonia denudata (Dillwyn) Kützing						C				
P. macrocarpa Harvey	C	R	C			C	C			
P. opaca (C. Agardh) Moris & De Notaris			R			C				
Spyridia filamentosa (Wulfen) Harvey		R				R				

Shallow Thalassia					*Diplanthera*					*Oyster Shells*					*Spartina Stems*					*Avicennia pneumatophores*				
A	S	N	J	M	A	S	N	J	M	A	S	N	J	M	A	S	N	J	M	A	S	N	J	M
																				C		R		C
R		R	R				R	R		R			R	R	R	C	R		R		C	R	R	C
C	C	C	C		R	C	C	R	R		R			C		R	C		C	R		R		
R		C	C	R	R	R	C	R		C		R	C	R	R	R	C		C		R	R		R
R		C	R	R		R	R	C	R	C	C		C		C	C	C		C		R	C	C	C
	C		R				R			C	C	R	A		C	C	C		C	C	C	C	A	C
					R																			
C	R	C	R		R	R	C	C		C		C			R		C		R	C	R	R		
C		R	C		C	R	C	C	C	R		C			R	R	R	C	R	R	R	R		
R		R		R			R			R	C	R		R	R	R					R	R	R	R
										R										R				
															R			R	R	C	R	R	R	
	R	R				R	R			R					R	R		C		C	R			
C		R			A	C	C			R	C	C			R		C			R		C		
																				C				R
C	C	C			C	R	C			R			R		C	C	R	C		C	C	C	C	R
				R																				
C	C				C	R	C		C		R				R	R				R	R			
R	R	C			A	C	C			R	R				R					C				
A	A	A	A	C	C	A	A	A	C		C	C		A	A	C	A	C	A	C	C	C	A	A
							R								R			C		R	R			
R					R		C								R					R	R			
C	C	C	R		C	C	R			R	C	C			C	R	C	C		R	C	C		
R														R	R									R
R	R	R																						
C	C	C	C	R	C	C	C			C	C	C	C	C	C	C	R		C	R	C	R	C	C
															R	R				R				
																					C			
																					A			
R					R						C			A	R	C			C	C	C			C
																			A					
					R					C	A	C			C	A	A	A	A	C		C	A	C
C															C					A				
R	R	R			C	C	R			C						R								
C															C									
A	C	A	C	C	A	C	A	C	A	A	A	A	A	A	A	A	C	C	A	A	C	C	A	A
C	R	C	C	R	C	C	C	C	C	C	A	A	A	A	C	C	C	C	C	C	C	C	A	A
C	C	A	C	C	A	A	A	C	C	A	A	A	A	A	A	A	C	C	A	C	C	C	A	A
													A					A					C	
		R					C	R									R				R			
	R		R			C		R	R															
C	C	R	R	A	A	C	R	C	A	C			C			R			C		R			
C			C		R																			
A	A	A	A	A	C	R	A	A	A						C					C		A		
																	C	C	C	A	C	A	A	A
R		R			C	R														A				
C					C	R																		

TABLE 3. Number of species occurring during each collection for each substrate (August 1975-March 1976). Numbers for *Thalassia* and *Syringodium* are composites of sites 1 and 1A.

Substrate	Aug.	Sept.	Nov.	Jan.	Mar.	Total Over All Dates
Thalassia testudinum	76	64	65	41	39	91
Syringodium filiforme	72	63	50	28	28	81
Shallow *Thalassia testudinum*	63	36	52	44	25	74
Diplanthera wrightii	51	48	42	35	32	71
Oyster shells	41	31	35	36	36	66
Spartina alterniflora	64	57	37	34	39	77
Pneumatophores	57	58	55	41	46	84
Total over all substrates	108	87	79	67	71	111

diversity of algal epiphytes on *Thalassia* leaves were least in early midsummer, just after the host plants had completed their most rapid growth, and that there was a gradual increase in epiphyte abundance and diversity from late August until the period of February 15 through March 15. For diatoms attached to *Thalassia* in Biscayne Bay, Reyes-Vasquez (1970) reported little seasonal differences; he agreed with Bass-Becking and Wood (1955) that in estuaries the underlying sediments associated with *Thalassia* are more important than temperature and salinity for these plants. The underlying sediments in the Cedar Keys area are largely combinations of hard packed sand and shell fragments (Reid, 1954). Here sediment composition and thickness would seem to be of less importance than that in Biscayne Bay because in some of Reyes-Vasquez's collecting areas the sediments were thick and soft.

The greatest numbers and relative abundance of algal species on the seagrass substrates occurred during August, September, and November. During December through February the flats of the Cedar Keys area experienced lower temperatures and increased exposure to the atmosphere. In these colder months, massive defoliation of the seagrasses occurs. Phillips (1960) and Strawn (1961) associated winter kill of seagrass leaves in this area with exposure. Low temperatures, however, would seem to be the more important factor, because large parts of the Cedar Keys flats (area adjacent to the study sites) not exposed during low tides also experience decrease in leaf area. Furthermore, in an area 160km south of Seahorse Key (Tampa Bay), McMillan (1979) offered experimental evidence that low temperature damages the leaves of *Thalassia*, *Syringodium*, and *Diplanthera*. Thus, in the Cedar Keys area, attachment sites for epiphytes decrease during the coldest months when the seagrasses largely die back to the buried, perennating rhizomes.

In addition to defoliation of seagrasses, low winter temperatures may directly affect the occurrence of algae. The winter macroalgal flora of the Cedar Keys (Hart, 1954), the Crystal River areas (Steidinger and Van Breedveld, 1971) and the Homosassa-Anclote Key area (Mathieson and Dawes, 1975) display many differences in species composition from that of the summer. Ballantine (1972) showed that temperature is an important factor responsible for the seasonality of a number of epiphytic marine algae, particularly in shallow water.

Unlike the seagrass leaves that largely disappeared during winter, the oyster shells, smooth cordgrass stems, and mangrove pneumatophores persisted throughout the study, thus representing important algal substrates during the cold months. However, it would seem that during most low tides organisms colonizing these drier substrates would be subjected to greater heat, salinity, and desiccation stresses than would those attached to wetter substrates. Some of the more abundantly occurring organisms on the drier substrates, particularly blue-green algae, are from algal groups well known for their ability to withstand such environmental stresses. Other organisms occurring in substantial numbers on these substrates, including *Melosira moniliformis, Polysiphonia denudata* and *Entermorpha flexuosa*, would also seem to possess the abilities to withstand environmental stresses. Fischer (1963) showed an intertidal *M. moniliformis* to be insensitive to fresh water and to resist without damage doubled sea water concentrations for up to 14 hr. Biebl (1962) demonstrated the ability of species of the latter 2 genera to survive 14–hr exposure to the atmosphere, provided a relative humidity of 82% was maintained. He also showed they were capable of withstanding salinity changes in the range of 0.1-4X seawater.

SUMMARY—From 5 monthly collections obtained during August 1975 to March 1976, 111 species of attached algae were found on seagrass leaves, oyster shells, smooth cordgrass stems and mangrove pneumatophores in the shallow marine waters near Seahorse Key, Florida. Seagrass leaves and smooth cordgrass stems always remained wet or damp, but the oyster shells and pneumatophores dried during low tides. Seventy-nine percent of the attached species were diatoms, the rest blue-green, green, red, and brown algae. During the warmer months, most species were found on seagrass leaves. A reversed distribution occurred during most of the coldest months and coincided with a massive defoliation of seagrass leaves at the study sites.

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REVIEW

J. B. Sidgwick, revised by James Muirden. *Observational Astronomy for Amateurs*, completely revised Fourth Edition. Pp. i-ix, 1-348. Enslow Publishers, Hillside, New Jersey. Price $5.95.

THE very fact that this is the fourth edition of this book indicates something of its value and its widespread use. It is not uncommon for an enthusiastic amateur to spend weeks or months constructing a small telescope and then to wonder just what might be done with it after the first bit of "star gazing" is over. This volume offers many suggestions.

Useful work on each of the planets is discussed in detail and other solar system phenomena (asteroids, comets, etc.) are also covered. Indeed the bulk of the book (pp. 1-248) is devoted to the solar system. However, variable stars, binaries, nebulae and clusters also receive attention. In the long chapter on variable, methods of visual observation are described in some detail, the different types of variables are described, and methods of reducing the observations are also covered. A table of Julian days from 1970 through 1995 is included, and even the equations for reducing the observations to the sun are given. For the latter, however, some other source for determining the sun's longitude on a given date must be available.

This is a major revision of an already established volume, including a new, extended 40-page bibliography, and is to be recommended even to those owning one of the earlier editions—*Frank Bradshaw Wood*, Department of Astronomy, University of Florida, Gainesville, Florida 32611.

A COMPARISON OF THE SPATIAL DISTRIBUTION OF *TILLANDSIA FLEXUOSA* AND *T. PRUINOSA*—*B. C. Bennett*, Department of Biology, the University of North Carolina, Chapel Hill, North Carolina 27514.

Abstract: *Compass orientation, vertical distribution and numerical distribution upon host species were determined for* Tillandsia flexuosa *Swartz and* T. pruinosa *Swartz.* T. flexuosa *was more abundant on E- and W-facing sides of its hosts.* T. pruinosa *was found more frequently in the E-facing microhabitat. Both species were found in the subcanopy. The most striking difference between the 2 species, with respect to spatial distribution, is their numerical distribution upon hosts.*

Little is known about the spatial distribution of vascular epiphytes. Of the 12 species of *Tillandsia* native to Florida only 1 has been intensively studied (Benzing, 1978a, 1978b, 1978c, 1981; Benzing and Renfrow, 1971, 1974, 1980). Bennett (1982) studied the spatial distribution of *Guzmania* and *Catopsis*. I will compare the spatial distribution of *Tillandsia flexuosa* Swartz and *T. pruinosa* Swartz, the rarest species of *Tillandsia* in Florida.

Tillandsia flexuosa has been reported from 10 counties in southern Florida. This species is found in several communities including mangrove swamps, cypress swamps and pine flatwoods. It is most abundant in former wetlands that have been partially drained. Pine flatwoods which support *T. flexuosa* are usually on or adjacent to former wet prairie or cypress habitats. Pine Jog Environmental Studies Center, Palm Beach County, was chosen as representative of sites that support *T. flexuosa*. *Tillandsia pruinosa* was examined in the Fakahatchee Strand State Preserve, Collier County, the only known locality of this species in the United States. Within the Fakahatchee Strand, *T. pruinosa* is confined mostly to mixed swamp communities.

Results and Discussion—Analysis of variance indicated that no host preference was exhibited by either species. As is the case with *Catopsis* and *Guzmania*, habitat preference is probably a more important factor than host preference (Bennett, 1982). The hosts on which the 2 *Tillandsia* species were found are in Table 1.

With respect to compass orientation, *Tillandsia pruinosa* was more common in the E-facing microhabitat. Differences were statistically significant (Fig. 1). The distribution of *T. flexuosa* did not differ significantly from a

TABLE 1. Common hosts which support *Tillandsia flexuosa* and *T. pruinosa* in southern Florida.

Species	
T. pruinosa	*T. flexuosa*
Acer rubrum	*Conocarpus erectus*
Annona glabra	*Laguncularia racemosa*
Fraxinus caroliniana	*Myrsine floridana*
Quercus virginiana	*Pinus elliottii*
Salix caroliniana	*Taxodium distichum*
Taxodium distichum	*Rhizophora mańgle*

random distribution with respect to compass orientation. This species was, however, found more frequently in the E- and W-facing microhabitats than in the N- and S-facing microhabitats (Fig. 2).

Neither bromeliad species were found in the canopy but both were confined to the subcanopy and trunk of their hosts. *Tillandsia flexuosa* occurred at an average height of 2.4 ± 0.7 m and *T. pruinosa* at an average height of 3.6 ± 1.6 m (Fig. 3).

The most profound difference in spatial arrangement of these bromeliads is their frequency distribution upon a host. The mean number of individuals differs substantially: *Tillandsia flexuosa* is strongly clumped ($\overline{Y} = 4.58 \pm 6.45$, N = 12, C.D. = 9.1) while *T. pruinosa* approaches a Poisson distribution ($\overline{Y} = 2.66 \pm 1.97$, N = 32, C.D. = 1.5). A coefficient of dispersion (C.D.) greater than one indicates a clumped distribution, less than one repulsed and one a Poisson distribution (Sokal and Rohlf, 1969).

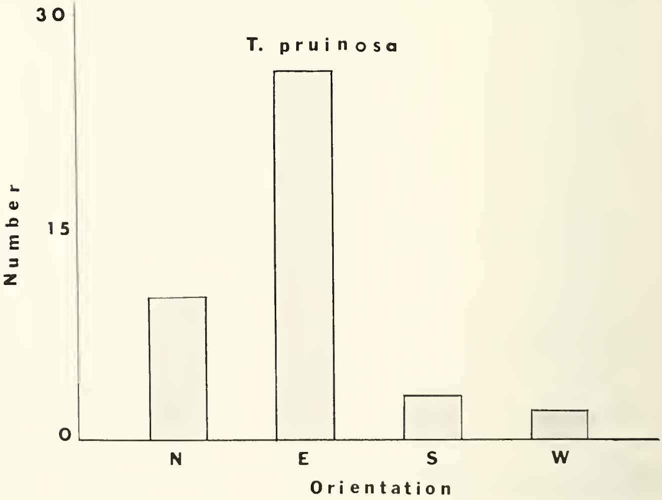

FIG. 1. Distribution of *Tillandsia pruinosa* with respect to compass orientation. Differences from a random distribution are significant (Chi-squared = 35.9).

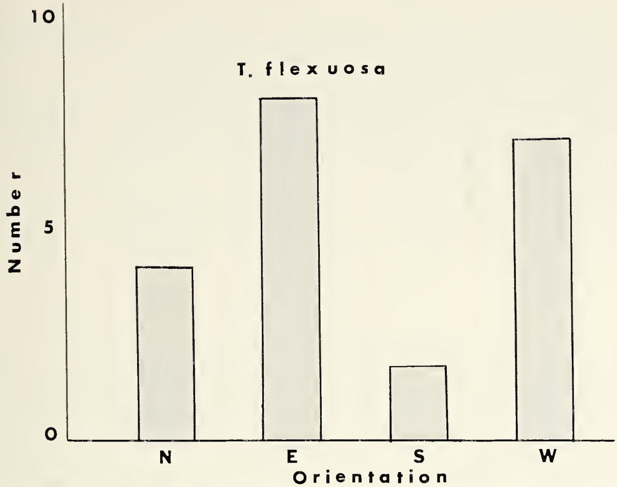

FIG. 2. Distribution of *Tillandsia flexuosa* with respect to compass orientation. Differences from a random distribution are not significant (Chi-squared = 4.33).

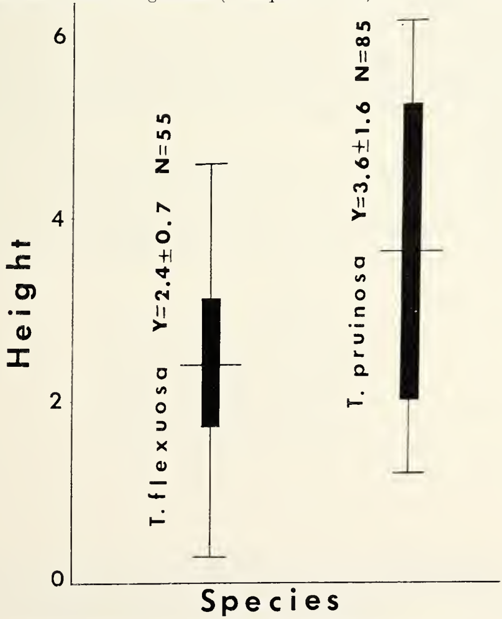

FIG. 3. Range, standard deviation and mean of the vertical distribution data for *Tillandsia flexuosa* and *T. pruinosa*.

The reasons for these differences in spatial distribution remain to be determined. Possibilities include lower seed set, germination rate and narrower environmental tolerances in *T. pruinosa*. Fruit production in both species is low, particularly in *T. pruinosa* which seldom produces more than 3 fruits. The production of vegetative offshoots is more frequent in *T. flexuosa*. The more efficient serial monocarpic strategy of *T. flexuosa* may result in increased autogenetic recruitment in this species and thus a greater degree of clumping than in *T. pruinosa*.

ACKNOWLEDGMENTS—The assistance of D. F. Austin, S. K. Austin and J. L. Jones (Florida Atlantic University) in the collection of field data is greatfully acknowledged.

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Social Sciences

RELATIONSHIP BETWEEN TOTAL ENERGY CONSUMPTION AND ECONOMIC ACTIVITY FOR THE FLORIDA ECONOMY, 1960-78

JAMES ZUCCHETTO

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Philadelphia, Pennsylvania 19104

ABSTRACT: *Analysis of the relationship between total energy consumption and Gross State Product and total income for the Florida economy were undertaken for the years 1960-78. Extremely robust relationships were found and the energy disruptions and price increases associated with the period 1973-74 seemed to have resulted in only a temporary decoupling between energy and economic activity. Relationships for 1977 and 1978 returned to pre-1973 levels.*

THE importance of energy for the support of the diverse activities associated with the growth, maintenance and reproduction of all living systems is a fundamental fact of human systems. For solar-based ecosystems, as well as human systems based on hunting, fishing or agriculture, the level of solar energy fixed by photosynthesis is of direct importance to the overall level of activity. In these predominantly solar-based systems energy fixed by photosynthesis can be traced through food webs to its point of use where work is accomplished and energy can serve as a common "currency" to measure the relative levels of work throughout a given system. In modern industrial societies the capture of solar energy is greatly augmented by fossil fuels and, more recently, nuclear fuels for the performance of work and the support of diverse activities (Fairgrieve, 1921; Cottrell, 1955; Hubbert, 1962; Odum, 1971; Adams, 1975; Cook 1976; Odum and Odum, 1981). Human economies use money as a mechanism for exchanging and distributing goods and services. However, the production and consumption of these goods and services depend to an intimate degree on available energy so that a close relationship between energy consumption and economic activity is hypothesized to exist for human economies.

The analysis between energy consumption and economic activity has been approached in basically 2 ways. From a macroscopic perspective the total economic output of an entire economy, such as measured by the Gross National Product, is compared to the total energy consumption of primary fuels to determine whether there is a consistent relation between these 2 variables in the form of an energy to gross output ratio measured in units of energy per unit of currency (e.g., Btu's/$ or Kcal/$). The basic notion is that an economic system is an "engine" powered by energy whose output is the production of goods and services. A macroscopic measure of this type can be defined for a world, national, regional or state economy as long as a consistent measurement approach within the prescribed boundaries of the economy under study is used (Barnett, 1950; Cook, 1971; Odum, 1971; Zucchetto, 1975; Schipper and Lichtenberg, 1976; Darmstadter et al., 1977; Zucchetto and Jansson, 1979). Other macroscopic measures could be defined such as energy consumption to total income. An overall macroscopic measure disguises variation within an economy. A more detailed analysis of activities would reveal significant variability in energy to economic measures across economic sectors. These measures could be calculated in a variety of ways including process and input-output analysis (Herendeen and Bullard, 1974). In my paper attention will be directed towards the macroscopic measure of energy consumption to gross economic output (hereafter called EGP). Even though this measure is an average of numerous internal activities it can still shed light on many questions related to energy and economies. For example, the EGP of an economy has been used as an indicator of efficiency with which an economy uses energy to produce economic output and comparative analysis among countries has revealed significant differences (Schipper and Lichtenberg, 1976; Darmstadter et al., 1977; Zucchetto and Walker, 1981) which leads to examination of why these differences exist and the potential for efficiency improvements. These international comparisons, however, are difficult to interpret because corrections must be made for climate, geographical size, spatial organization, industrial mix, technology, prices, culture, human behavior patterns and a host of other variables.

Many of these difficulties are eliminated if only a given economy is considered over time. Because physical geography and the structure of the economy do not change all that quickly, a number of time series measurements over a period of years can help to indicate whether changes which are occurring in the EGP measure are a result of increasing efficiency. Over longer periods of time one must try to account for structural changes, such as the percentage of heavy industry in comparison to service industries, because these 2 sectors have very different energy intensities. Monitoring the consistency of energy to economic measures will give some indication of the extent to which increased efficiency is possible. If there is a consistent relationship then this has implications for energy as well as economic planning and policy. If it is desirable to maintain or increase economic output then this goal must be judged in light of the availability of required energy. On the other hand, if improvements in energy efficiency seem attainable then the limits to which improvements can be made will aid in planning economic growth in conjunction with anticipated reduction in requirements for energy. Information along these lines can help in reducing the economic costs associated with investment in energy production facilities and lead to a more efficient use of available capital. Analysis of the energy-economic measures can, as previously mentioned, be conducted for subareas of a national economy to determine whether significant regional differences exist: this more specific regional information can lead to better planning at this level. In particular, the present paper focusses on an analysis of the energy-economic relationships for the State of Florida with the use of time-series data from 1960 to 1978.

Analysis of Energy-Economic Measures for Florida, 1960-78—To quantify the relationship between energy and the Florida economy, data were collected for 1960 to 1978. These data included time series measures of Gross State Product (GSP), total personal income (hereafter called income), and total primary energy consumption (E) which were gathered from statistical sources (Florida Statistical Abstracts, 1968-80; Niemi, 1975). GSP data were converted to real terms and expressed at 1972 prices, and total energy consumption data were converted to the common energy unit of Kcal. These results are summarized in Table 1. During this time period an almost continuous growth of economic output, income, and energy consumption has occurred. A graph of GSP as a function of E is presented in Fig. 1 with the results of a linear regression between the 2 variables. The 2 important aspects of this graph to note are the very strong correlation between energy and economic output as well as the data points for the years 1973 to 1976. The oil embargo of 1973 with consequent price disruptions and economic effects in the period 1973-75 seems to have altered behavior so that economic output per unit of energy was enhanced (points lying above the regression line) but then the economy returned to "normal" behavior as the years 1977 and 1978 are recorded. This can be further noted in Table 1 and Fig. 2 by observing the changes in the energy to output ratio (E/GSP) which declined in 1973 to 1975 relative to 1972 and then increased in subsequent years to levels higher than 1972. Fig. 2 vividly illustrates the uniformity in the E/GSP measure with small variations about the mean. The relationship is not quite as consistent for the energy to income ratio. A set of linear and log-linear regressions were conducted to quantify the degree to which these energy and economic measures were correlated and the variables used are defined as follows. E = Total energy consumption in trillions of Kcal; GSP = Gross State Product in billions of dollars at 1972 prices; INC = total personal income in billions of dollars at 1967 prices; ΔGSP = change from year to year in Gross State Product in billions of dollars at 1972 prices; ΔE = change from year to year in energy consumption in trillions of Kcal. The regressions are as

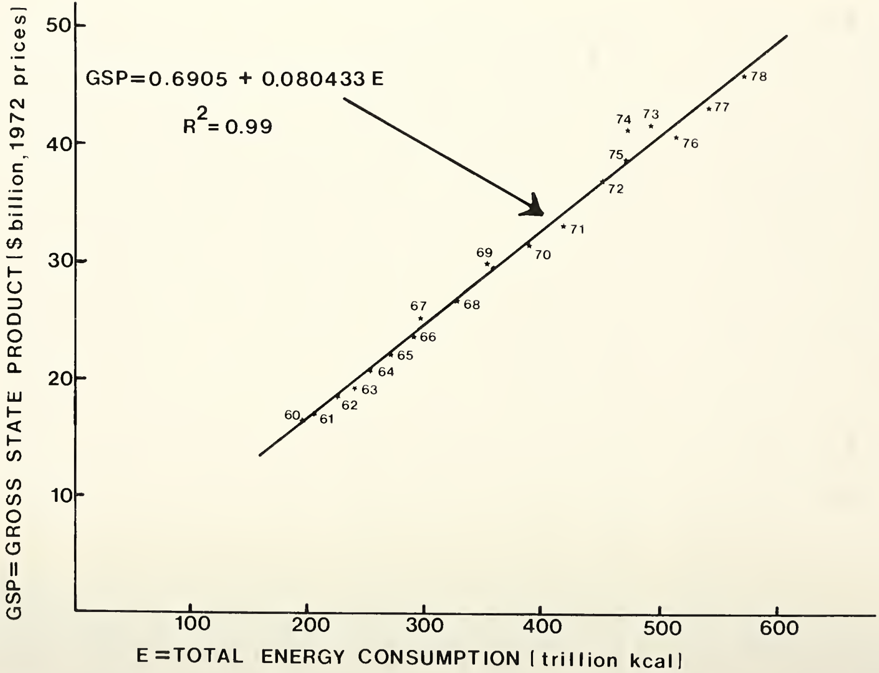

Fig. 1. Correlation of total gross state product vs. total energy consumption for Florida with data points for 1960-78.

TABLE 1. Gross State Product, total energy consumption, total income and energy-economic measures for Florida, 1960-78.

Year	G.S.P.[1]	Energy[2]	Income[3]	E/G.S.P.[4]	E/Income[5]
1960	16.6	196	—	11814	—
1961	17.2	205	—	11940	—
1962	18.6	226	12.3	12148	18374
1963	19.3	240	13.0	12443	18462
1964	20.9	253	14.0	12091	18071
1965	22.3	270	15.1	12120	17881
1966	23.6	290	16.3	12274	17791
1967	25.2	295	17.6	11705	16761
1968	26.9	326	19.2	12136	16979
1969	30.0	354	20.8	11796	17019
1970	31.4	387	21.8	12330	17752
1971	33.1	416	23.3	12569	17854
1972	37.0	450	26.3	12166	17110
1973	41.6	492	29.1	11826	16907
1974	41.2	471	29.3	11439	16075
1975	38.9	472	28.9	12141	16332
1976	40.6	511	29.9	12594	17090
1977	43.1	542	31.4	12582	17261
1978	46.0	571	33.3	12413	17147

[1] Gross State Product in billions of dollars at 1972 prices.
[2] Energy expressed in trillions of Kcal.
[3] Income expressed in billions of dollars at 1967 prices.
[4] Ratio of energy consumption to gross state product (Kcal/$ at 1972 prices).
[5] Ratio of energy consumption to total income (Kcal/$ at 1967 prices).

follows with t-statistics indicated in parenthesis under the coefficients, the correlation coefficient, and the years of data used in parenthesis under the correlation coefficient:

$$1)\quad \underset{}{GSP} = \underset{(0.97)}{0.6905} + \underset{(43.8)}{0.080433}(E) \qquad \underset{(1960\text{-}78)}{R^2 = 0.99}$$

$$2)\quad \ln(GSP) = \underset{(-22.6)}{-2.3801} + \underset{(54.5)}{0.9803}(\ln E) \qquad \underset{(1960\text{-}78)}{R^2 = 0.99}$$

$$3)\quad INC = \underset{(-2.33)}{-1.4691} + \underset{(39.5)}{0.061921}(E) \qquad \underset{(1962\text{-}78)}{R^2 = 0.99}$$

$$4)\quad \ln(INC) = \underset{(-22.7)}{-3.3499} + \underset{(43.6)}{1.0841}(\ln E) \qquad \underset{(1962\text{-}78)}{R^2 = 0.99}$$

$$5)\quad \Delta GSP = \underset{(0.23)}{0.099144} + \underset{(4.5)}{0.073641}(\Delta E) \qquad \underset{(1960\text{-}78)}{R^2 = 0.56}$$

There is extremely strong correlation between the energy and economic variables for regressions 1 to 4 with a more modest though significant relationship for the correlation of changes from year to year reflecting annual variability. The slopes of the regressions (1 and 3) can be used as an average measure of the GSP or INC produced for each unit change in energy con-

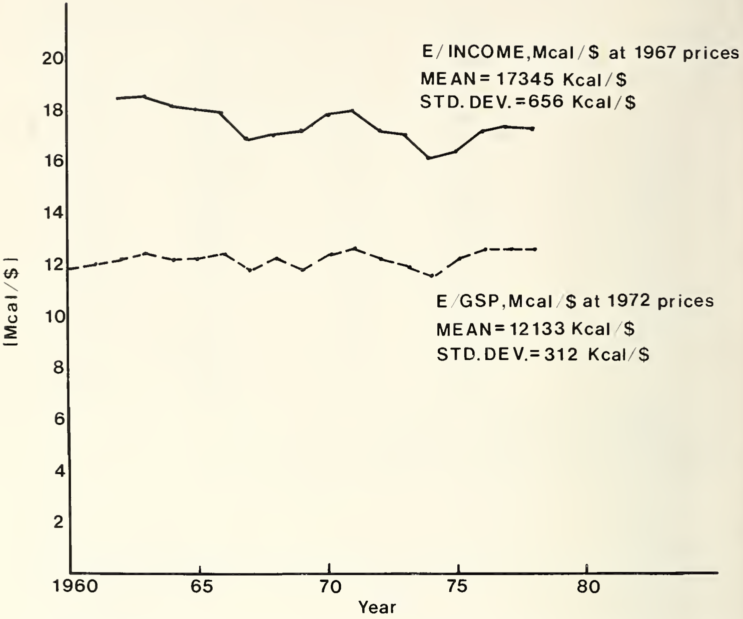

Fig. 2. Graph of the energy to income (——) and energy to gross state product (--------) ratios over time, 1960-78.

sumption. The slopes of the log-linear regressions (2 and 4) represent the percent change in the economic measure for a percent change in energy consumption (e.g., d(GSP)/dE ÷ dE/E; d(INC)/INC ÷ dE/E and these are nearly equal to one. Again, reference to Fig. 2 also seems to indicate a strong consistency in energy to economic ratios over time and if these ratios are interpreted as the amount of energy required per unit of output then this overall measure has remained remarkably uniform over time. The above regressions have presented energy as the "independent" variable and many analysts prefer this because energy is identified as the "driving" force for the economy, the principal forcing function. However, many ask the question: "For a given level of economic output how much energy is required?" and the economic measure is chosen as the independent variable. For those preferring this approach the following regressions are presented where the variables are the same as above:

$$\begin{array}{lll}
1) & E = -5.2835 + 12.323(GSP) & R^2 = 0.99 \\
 & \qquad (-0.6) \qquad (43.8) & (1960\text{-}78) \\
2) & \ln(E) = 2.4473 + 1.0143(\ln GSP) & R^2 = 0.99 \\
 & \qquad\qquad (39) \qquad (54.6) & (1960\text{-}78) \\
3) & E = 27.174 + 15.996(INC) & R^2 = 0.99 \\
 & \qquad (2.86) \quad (39.5) & (1962\text{-}78) \\
4) & \ln(E) = 3.1122 + 0.9152(\ln INC) & R^2 = 0.99 \\
 & \qquad\quad (48.1) \qquad (43.6) & (1962\text{-}78)
\end{array}$$

These are of high significance again but the coefficients have changed; the elasticities of energy consumption with respect to economic output and income are again near to one as can be seen from the log-linear regressions.

Discussion and Conclusions—What implications do the preceding results have? For an energy analyst indulging in efforts to generate theories concerned with the relationship between energy and economics the preceding results lend support to the hypothesis that there is a relatively invariant relationship between energy consumption and gross economic output, at least for the Florida economy. The "rebound" of the relationship subsequent to the 1973 energy shock seems to indicate that no long term gains in efficiency, at least as measured by an energy-economic output ratio, accrued up until 1978. It could be argued that structural changes in the economy such as the expansion of energy intensive heavy industry would tend to increase the energy-economic output ratio and disguise increases in energy efficiency that might have evolved. However, as can be judged from Table 2, there does not seem to have been any major change in the structure of the economy and, in fact, heavy industry seems to have declined as a proporation of total gross state product. Because less energy intensive activities are contributing a greater proportion to economic output this should influence the E/GSP ratio in a downward direction. Furthermore, an analysis of temperature records for several years indicated erratic variation in cold to warm winters and summers without correlation or association with the E/GSP ratio. This would seem to lend further support to the notion of a robust energy-economic correlation. Another remarkable result of this analysis is that the results for Florida are very much different than for the United States as a whole. For the U.S. the ratio of energy consumption to Gross National Product declined from 1973 to 1980 during which time real GNP increased at an annual yearly rate of 2.65%, while energy consumption rose 0.88% a year (U.S. D.O.E., 1980). Thus, the difference between a state economy and the U.S. economy in this respect is striking.

Aside from the theoretical interest is the practical planning problem of projecting energy consumption based on economic projections or vice-versa for which the preceding results can aid in more accurate projections. Perhaps the Florida economy has not been responsive to the energy shock of

TABLE 2. Percent contribution to the Gross State Product of Florida by broad industrial source for selected years.*

CATEGORY	1960	1970	1971	1972	1973	1974	1975	1976	1977
Private Heavy Industry (1)	21.4	20.7	20.0	20.4	21.3	20.3	18.0	16.8	17.0
Other Private Activities (2)	61.2	62.0	62.8	62.7	62.5	63.1	64.0	65.4	65.3
Farm	4.7	2.9	3.1	3.0	3.0	3.0	3.2	2.8	3.2
Government (3)	12.7	14.2	14.1	13.8	13.2	13.6	14.6	15.1	14.5

*Table constructed based on information from Florida Statistical Abstracts.

[1]Includes mining, contract construction and manufacturing.

[2]Includes transportation, communications, public utilities, wholesale and retail trade, finance, insurance, real estate, services, agricultural services, forestry and fisheries.

[3]Includes state and federal.

1973 for several reasons: a significant part of the economy is tourist related and vacationers may not tend to behave in an energy conserving manner; there is not as much room for energy conservation in heating because of the relatively mild winters; a fast growing economy like Florida's may tend to be more energy intensive than an economy which has more time to adjust and organize patterns of efficient behavior. These suggestions are, at best, speculations but more extensive time-series analysis in the future is eagerly looked forward to in order to determine whether this energy-economic coupling remains as robust as indicated herein.

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Earth Sciences

A SEISMIC REFRACTION PROFILE OF THE NORTH FLORIDA CRUST

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Abstract: *A seismic refraction profile trending northwest-southeast and extending approximately 50 km from Newberry (Alachua County) to Lowell (Marion County), Florida was conducted with quarry blasts as energy sources and portable earthquake seismographs as detectors. The travel time data limited the analysis to a simple 2 layer model with an upper unit velocity of 3.66 ± 0.25 km/sec and a lower unit velocity of 6.25 ± 0.15 km/sec. The upper layer is interpreted to represent the Coastal Plain and underlying Paleozoic sedimentary rock sequence, while the lower layer is considered representative of crystalline basement such as the granitic Avalon Complex. A depth of 3.50 ± 0.2 km is computed for the interface, closely approximating previously published estimates based on gravity data.*

Applin's (1951) investigation of deep drill hole cores from Florida permitted him to describe a north-central Florida basement consisting of early Paleozoic sedimentary rocks which pinched out to the south against a subsurface granitoid mass. Depths to the Paleozoic rocks were well-documented, and in Alachua County, the overlying Coastal Plain sedimentary thickness was fixed at approximately 970 m. No drill hole, however, had at that time penetrated the sedimentary sequence and none has yet done so. Despite Applin's report of "over 2000 feet" of Ordovician sandstone, our knowledge of the thickness of this important wedge of continental clastic sediments and the depth to the true basement is only conjectural.

We provide independent evidence from a local seismic refraction profile for the depth to the basement in Alachua County, Florida. Travel time measurements by portable seismographs from quarry blasts were used to determine compressional (P) wave velocities within the upper crust and to compute a thickness for the low-velocity, sedimentary sequence for north Florida.

Florida Basement—In northern peninsular Florida, subsurface layers of Ordovician sandstone and Silurian sandstone and clay represent the deepest rocks penetrated by deep boreholes (Applin, 1951; Barnett, 1975). Barnett (1975) described the basement for this region as the sub-Zuni surface and predicted a still deeper Cambrian-Precambrian granitic basement beneath the Paleozoic sedimentary rocks. Banks (1978) grouped the sub-surface Paleozoic sedimentary rocks in the Tippecanoe deposition sequence and termed them the Suwannee Basin rocks. The adjacent (and perhaps underlying) granitic rocks were labeled the Avalon Complex. Figure 1 depicts the general distribution of basement rocks in north Florida.

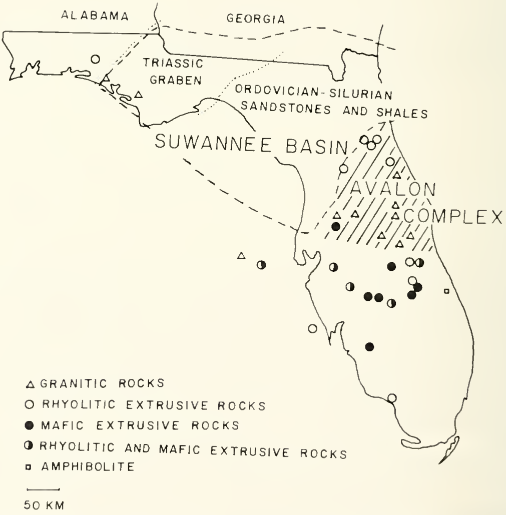

Fig. 1. Distribution of basement rocks on the Florida Plateau. Dashed lines depict the Suwannee Basin of subsurface Paleozoic sedimentary rocks, as indicated by numerous boreholes (not shown). The western third of the Suwannee Basin is dominated by a northeast-trending graben filled with Triassic sedimentary rocks. All boreholes encountering igneous rocks other than diabase dikes associated with the Triassic graben are shown. The region of granitic and rhyolitic basement is labeled Avalon Complex. Data are from sources cited in the text.

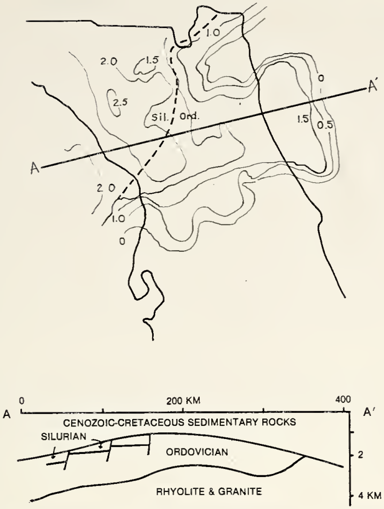

FIG. 2. Isopach map of the Paleozoic sedimentary rocks in the north Florida basement (from Wicker and Smith, 1978).

Depths to the Suwannee Basin sediments range from 832 m to 981 m below the surface in Alachua County. The closest borehole to the study area penetrated Paleozoic rocks at a depth of 956 m. Using well data, Wicker and Smith (1977) prepared an isometric view of the sub-Zuni Florida basement which, in Alachua County, is portrayed as having its top approximately 1,000 m below the surface.

In a subsequent re-evaluation of the Florida basement (Wicker and Smith, 1978), observed Bouguer gravity anomalies were duplicated from a computer-derived model of subsurface rock unit densities and thicknesses. A depth to the Paleozoic rocks was placed at approximately 950 m for Alachua County, but more significantly, an isopach map for the Paleozoic Suwannee Basin sediments was determined (Fig. 2). The thickness of the Suwannee Basin Tippecanoe rocks in the study area, according to Bouguer gravity anomaly interpretations, is approximately 2.0 km. Thus, the theoretical depth to the base of that sequence, and the granitic basement would be 2.95 km (Wicker and Smith, 1978).

METHODS—Three portable seismographs were used to monitor five blasts at the Dickerson, Inc., Haile quarry (Fig. 3) 4 km northeast of Newberry, Florida, over a six week period during the spring of 1981. One instrument was always placed at the quarry itself, within 75 m of the shotpoints, to determine an accurate shot origin time. The other instruments were placed at various locations and moved after each individual shot. The University of Florida seismograph station, station GAI in Gainesville (described by Smith, 1978), was used as a recording site for 1 shot.

Station GAI rests on the Hawthorne Formation, but the seismometer is coupled to the Crystal River Formation of the Ocala Group. All the portable stations and the shot point site were located on the Crystal River Formation. This formation is a late Eocene, massively-bedded bioclastic limestone that dominates the surficial geology of western Alachua and Marion counties.

The resulting seismograph array was generally oriented in a northwest-southeast direction (Fig. 3). The profile extends from the Haile quarry northeast of Newberry through western Alachua County and into northwestern Marion County. Specific sites for the portable seismographs were chosen for their distance from normal human activity to reduce background noise and avoid significant signal attenuation. Geographic coordinates for each station were determined from United States Geological Survey 7.5 minute quadrangle topographic maps.

Instrumentation for this study consisted of 3 Sprengnether MEQ-800 portable seismographs and seismic station GAI, a fixed station Sprengnether SS-80 seismograph located on the University of Florida campus. Sprengnether L4 short period (1 second), vertical seismometers were used as detectors. The system has variable amplification and bandpass filters to allow removal of unwanted frequencies without significant loss of signal. A digital quartz chronometer provides continuous time intervals which can be synchronized with the National Bureau of Standards radio time broadcasts. Recording paper speed for this study was 120 mm/min. This permitted an accuracy of recorded readings to be within ± 0.05 seconds when viewed with a calibrated miscroscope.

A smoked paper system was used in which a sooted paper was scratched by a simple stylus. Paper smoking was accomplished by rotation of a paper coated drum over a kerosene lamp that used a 1:1 mixture of motor oil and kerosene. The smoked paper records were made permanent by coating with a 50:1 mixture of ethanol and shellac. Figure 4 is an example of a seismogram recorded in this study.

TABLE 1. Time—distance data for recorded shots.

Station	Distance (km)	Travel Time (sec)
Jonesville	5.68	1.55
West Farms	16.04	4.10
Station GAI	22.85	5.25
East Williston	35.70	7.20
Lowell quarry	51.15	9.75

RESULTS—Table 1 gives arrival times and distances from shotpoints. Timing accuracy (± 0.05 sec) was achieved by using a 15 power microscope with a vernier scale calibrated to ± 0.02 mm. Arrival times were plotted against shot recorder distance (Fig. 5), and a simple 2 layer model emerged. Slope inversion (Dobrin, 1976) yields upper and lower layer compressional (P) wave velocity values of 3.66 ± 0.25 km/sec and 6.25 ± 0.15 km/sec, respectively.

The lesser value (3.66 km/sec) represents an average velocity for the sedimentary rock sequence which includes the Coastal Plain rocks and the underlying Suwannee Basin rocks. This value compares favorably with an average of published values (Clark, 1966) for soft limestone (1.7-4.2 km/sec), sandstone (1.4-4.3 km/sec), and shale (1.1-2.5 km/sec). Average velocity values generated from a transit-time log of the COST no. GE-1 deep well located approximately 120 km east of Jacksonville, Florida, ranged from 2.5 km/sec for upper Eocene limestone to 3.5 km/sec for late Cretaceous clastics and 5.6 km/sec for undifferentiated Paleozoic (?) sedimentary rocks (Anderson and Taylor, 1979).

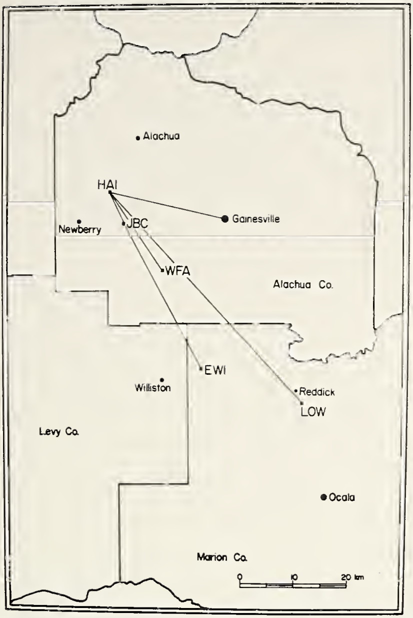

FIG. 3. Map of Alachua and adjacent counties with seismic station sites indicated as HAI: Haile Quarry; JBC Jonesville Baptist Church; WFA: West Farms; EWI: East Williston; and LOW: Lowell Quarry.

The lower layer velocity value (6.25 km/sec) is interpreted as representative of an underlying crystalline basement that may be an extension of the granitic Avalon Complex. P-wave velocity values for granite are typically 5.5-5.6 km/sec (Clark, 1966), and velocities of 5.57 km/sec and 6.50 km/sec are considered representative of the upper and lower crust, respectively. Thus, the observed lower layer velocity for north Florida is suggestive of an intermediate crust, perhaps similar to the pervasively intruded continental crust with seismic velocities of 6.2 km/sec (sialic) and 8.1 km/sec (ultramafic) proposed for the Bahamas and south Florida (Mullins and Lynts, 1977).

Using the equation (Dobrin, 1976)

$$Z = \frac{t_i}{2}\left[\frac{V_1V_2}{(V_2^2 - V_1^2)^{1/2}}\right]$$

where Z is the depth of the interface between layers 1 and 2 and t_i is the time axis intercept, a depth to the interface was calculated to be 3.50 km ± 0.2 km. The magnitude of possible error was determined from the error limits of timing and distance for the seismic profile. This value approximates the pro-

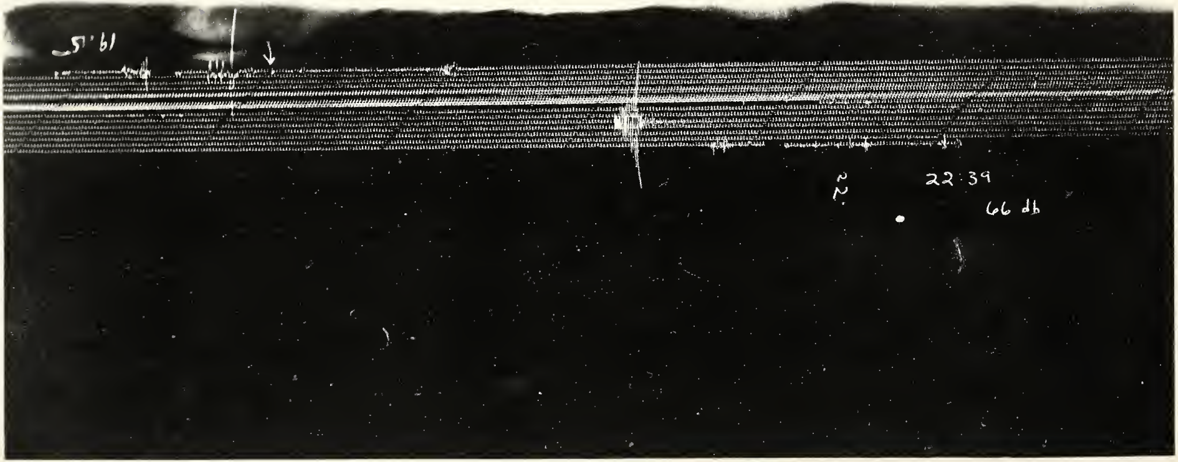

FIG. 4. Typical seismogram of quarry shot. Notice clarity of signal arrival. Single time picks are every second. One second duration picks are every minute.

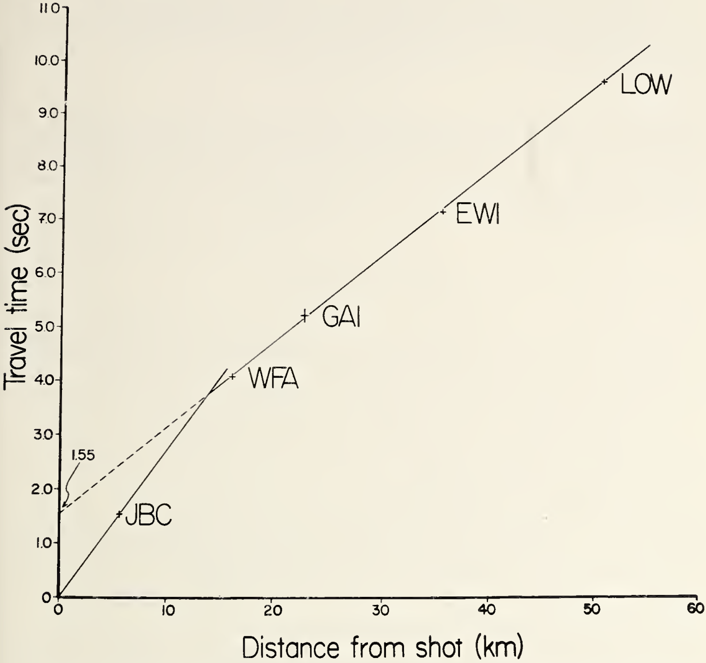

FIG. 5. Travel time curve of recorded times and measured distances. Abbreviations are for stations located in Fig. 3.

posed depth (Wicker and Smith, 1978) of 2.95 km to the base of the Paleozoic sedimentary rocks on the basis of gravity anomalies. Thus, the thickness of the Paleozoic sedimentary rocks underlying the north Florida peninsula is more than twice the thickness of the Cretaceous to Recent Coastal Plain sequence in Alachua County.

SUMMARY—A refraction profile extending approximately 50 km in western Alachua County and northwestern Marion County utilized quarry blasts as a seismic source and portable earthquake seismographs as detectors. A simple, 2 layer interpretation of the travel data yields an upper layer velocity of 3.66 km/sec which is interpreted as indicative of the Coastal Plain sedimentary rock sequence and the underlying Paleozoic sandstones and shales. The overall thickness of this acoustic unit is placed at 3.50 km, which can be compared to the depth of 2.95 km proposed by Wicker and Smith (1978) for the base of the Paleozoic sedimentary rock sequence.

A lower layer velocity of 6.25 km/sec is considered representative of a basal crystalline mass, probably the granitic or altered granitic Avalon Complex. This value is within the range of typical P-wave velocity values for the crust and is similar to those previously proposed for an intermediate crust for the Bahamas Platform.

ACKNOWLEDGMENTS—We appreciate the generous assistance of Gil Bolinger, Virginia Polytechnical Institute and State University for the loan of 3 portable seismographs and invaluable instruction in their operation. We also thank the Dickerson Corporation and Southeastern Minerals Corporation for their gracious consent to monitor quarry blast operations. D. S. Jones critically reviewed the manuscript and offered many helpful suggestions.

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CHRYSOPHYCEAE (MALLOMONADACEAE) FROM FLORIDA

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Abstract: *A brief comment with scanning and transmission electron micrographs is given for 19 species and varieties of Chrysophycean genera occurring in Florida lakes and rivers. Two taxa have not been reported previously from North America.*

Phytoplankton from Florida lakes has been little investigated for their Chrysophycean flora. This paper deals with species and varieties occurring in selected pools, lakes, and rivers in central Florida. Although there have been a number of studies on North American scaled chrysophytes, to-date only 1 examination of Florida freshwater phytoplankton have been made using electron microscopy (Wujek, 1983).

Electron microscopy has become a necessity to make accurate taxonomic determinations for most taxa of the Mallomonadaceae, including *Mallomonas*, *Synura*, *Chrysosphaerella*, *Chromophysomonas*, *Paraphysomonas*, *Mallomonopsis*, *Spiniferomonas*, and *Chrysodidymus*. Species identification of these taxa utilizes the morphology and structure of siliceous scales, spines, and bristles. Wee (1982) presents the most recent review of these terms with numerous illustrations.

It was considered of value to publish the present electron micrographs to provide a better understanding of the distribution of the Mallomonadaceae, as well as point out to the limnological researchers in Florida some of the scaled chrysophytes they may encounter in the plankton.

Materials and Methods—Details of collection and transmission electron microscopy (TEM) sample preparation for this study were published previously (Wujek, 1983; Wujek and Van der Veer, 1976). Samples for scanning electron microscopy (SEM) observations were prepared by air-drying material on aluminum stubs. In a few instances, material collected on Nucleopore filters was critical point dryed. TEM observations were made using either a Philips 200 or Hitachi H-500, while SEM observations using gold coated specimens were made using a Novascan 30.

All samples were collected from 18 January to 15 April 1982. The specific localities are in Table 1.

Observations and Discussion

Chrysodidymus, first described in 1962 by Prowse, is a 2-celled colony, with the cells attached at their posterior end. Individual cells are narrow and long to almost spherically shaped and possess two subequal flagella.

Chrysodidymus synuroides Prowse Figs. 1-2. A taxon recently reported for the United States from Michigan and Minnesota (Wujek and Wee, 1983), my Florida collections represent its most southern report for North America.

TABLE 1. Collecting sites sampled for scaled chrysophytes.

- Clay County
  - Lake Brooklyn
- Hillsborough County
  - Sink Hole (R19E T28S Sec. 1)
  - Bog (R20E T27S Sec. 33, 34)
  - Lake Thonotosassa
  - Lake Brooker
  - Hillsborough River
- Lee County
  - Sail Fish Canal
  - Sanabel Island ditch
  - Cypress Lake
- Polk County
  - Lake Parker
  - Two small lakes (unnamed) on Hwy 50 at east city limits of Winter Haven
- Putnam County
  - Lake Mc Cloud
  - Lake Adaho
- Sarasota County
  - lower Lake Myakka
  - upper Lake Myakka
  - Myakka River
  - Saddle Creek
  - Ponds on entry road to former K. C. Royals practice fields

This is consistent with its original description site of Malaya. Other reported localities have included Greenland, Japan and Chile (Dürrschmidt, 1982a; Wujek and Wee, 1983). The species was abundant in the bog when originally collected in January, but within a month, it was absent from subsequent samples.

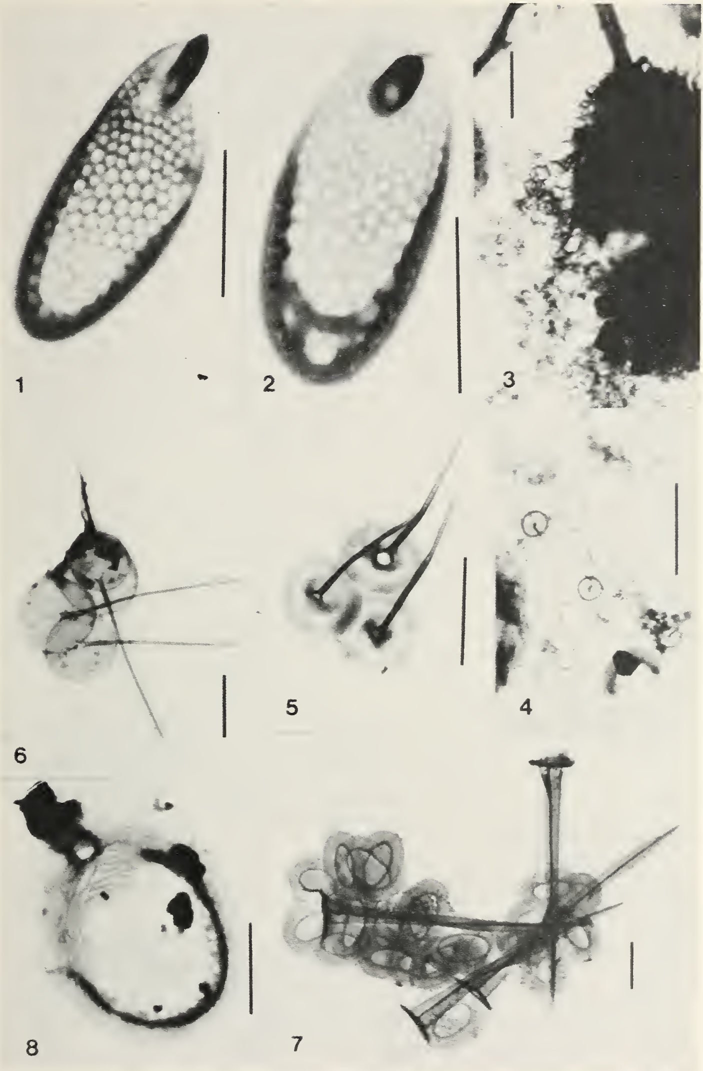
Paraphysomonas is a colorless, single-celled flagellate, which, like other members of the Mallomonadaceae, has numerous siliceous scales surrounding the protoplast. With the most recent descriptions of 9 new freshwater species (Thomsen et al., 1981; Wujek, 1983), 37 freshwater and marine taxa are now recognized. Of this number, only 2 are readily recognized using light microscopy.

Paraphysomonas bandaiensis Takahashi Figs. 3-4. This species belongs to what Thomsen et al. (1981) have termed the nail-shaped group. The scale has a short spine with a very pronounced rim on the base-plat.

This represents its first report for the United States, having been reported previously from Japan (Takahashi, 1976, 1978), England (Hibberd, 1979; Preisig and Hibberd, 1982), Holland (Roijackers, 1981) and Canada (Nicholls, 1981). I observed it from Lake Brooker.

P. imperforata Lucas Fig. 5. This second most frequently reported species of the genus was first reported in North America from Arkansas by Andersen (1978). This represents its second record for North America. It was mentioned by Wee et al. (1976) as occurring in Iowa, but their identification is in fact a Heliozoan species. I observed this species from samples collected from Lake Brooker.

P. vestita (Stokes) de Saedeleer Fig. 6. This most widely reported species of *Paraphysomonas* has been illustrated in a number of publications reporting it for the United States (Thompson and Halicki, 1965; Wujek and Hamilton, 1973; Andersen, 1978; Gretz et al., 1979). This species, like the 2 proceeding species belongs to the nail-type group. It was found in the Sink Hole, Bog, Lake Brooker, Kansas City ponds, and Saddle Creek.



Figs. 1-2. *Chrysodidymus synuroides*. Figs. 3-4. *Paraphysomonas bandaiensis*. Fig. 5. *P. imperforata*. Fig. 6. *P. vestita*. Fig. 7. *Chromophysomonas trioralis*. Fig. 8. *Synura echinulata*. *Scale bar* = 1 um.

Chromophysomonas consists of unicellular nannoplankton species which are covered with siliceous scales and spines. The genus was recently reviewed by Nicholls (1981), who included descriptions of 2 new species. Most taxa now placed in the genus were originally placed in *Spiniferomonas* Takahashi, but Preisig and Hibberd (1982) have shown the types species S. *bourrellyi*, to be unpigmented.

Chromophysomonas trioralis (Takahashi) Preisig and Hibberd Fig. 7. This species is probably the most common of the 8 species which are now recognized. The species has oval scales with a central lacuna and stout, 3-sided spines. Described from Japan (Takahashi, 1973), it has since been reported over 20 times worldwide, with its most recent report for the United States coming from Minnesota (Wujek et al., 1981b). In Florida it was found in the Sink Hole.

Cells of *Synura* are radially united in spherical to oblong-ovoid colonies that are not enclosed within a gelatinous sheath. Individual cells are biflagellate, pyriform, and covered with siliceous scales without bristles. Petersen and Hansen (1956, 1958) were the first to illustrate and describe the scales of this genus using electron microscopy including descriptions of several new forms.

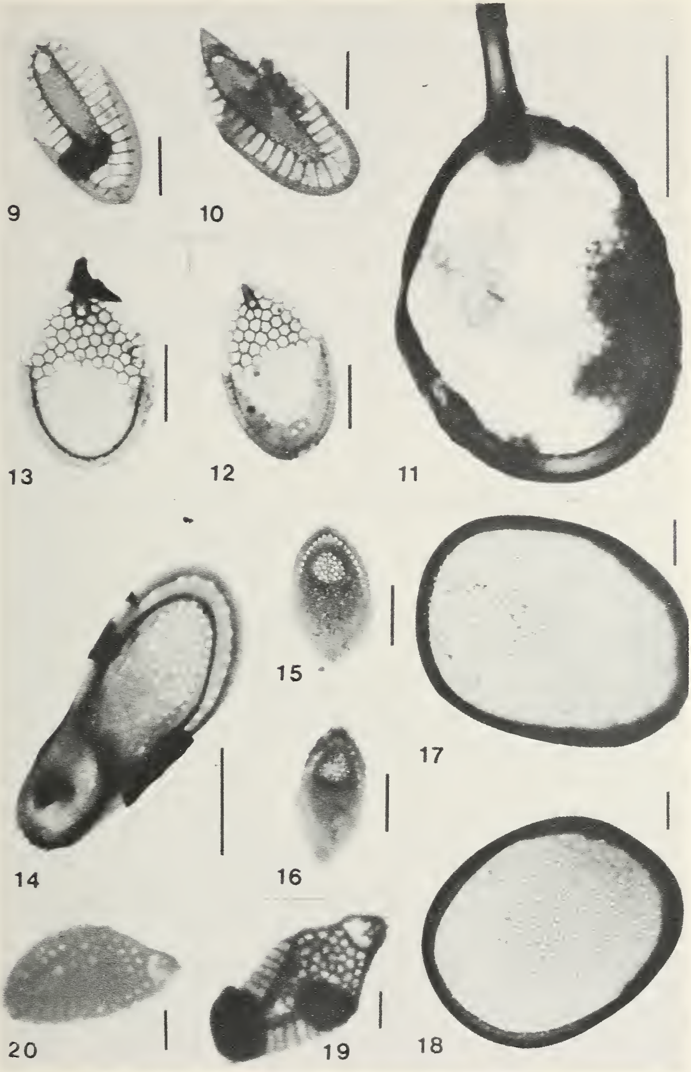
S. *echinulata* Korshikow Fig. 8. The scales have a distinctive pattern on their distal part. The apical scales have prominent spines which may be perforated. Posterior scales either lack or have reduced spines. This species was found in the Sink Hole and lower Lake Myakka.

S. *petersenii* Korshikov Figs. 9-10. This is the most common *Synura* species reported worldwide. In the United States, it has been reported 7 times (Wujek et al., 1981b). Locations in Florida for this species include Sink Hole, Bog, lower Myakka Lake, Saddle Creek and Lake Adaho.

S. *sphagnicola* Korshikov Fig. 11. Only a few scales of this species were observed from the Bog and never the whole colony or intact cells. Although apparently wide spread in Europe, there have been only 4 reports of this species from the western hemisphere (Canada-Puytorac et al., 1972; Minnesota-Wujek et al., 1981b, Michigan-Wujek and Hamilton, 1972; Alaska–Asmund, 1968).

S. *curtispina* (Peterson and Hansen) Asmund Figs. 12-13. A species with scales that possess a short spine terminating in 3 or 4 teeth. A form, *reticulata* Asmund, is also recognized. Like S. *petersenii*, this species is also widely distributed. It was from the Sink Hole. Previous U.S. localities for this taxon are Michigan (Wujek and Hamilton, 1972) and Arkansas (Andersen and Meyer, 1977).

Cells of *Mallomonas*, a unicellular freshwater genus and the largest genus within the Mallomonadaceae, bear siliceous scales and bristles and in one species, a third type of covering, termed a cyathus. Cells in the light microscope appear to be uniflagellate, but the presence of a very reduced second flagellum has been documented (Takahashi, 1975; Wujek, 1978).



Figs. 9-10. *Synura petersenii*. Fig. 11. *S. sphagnicola*. Figs. 12-13. *S. curtispina*. Figs. 14-16. *Mallomonas akrokomos*. Figs. 17-18. *M. caudata*. Figs. 19-20 M. crassisquama. Scale bar = 1 um.

M. akrokomos Ruttner Figs. 14-16. One of the most frequently occuring species worldwide, probably because it is eurythermal, although it is most frequently observed from cooler waters (Dürrschmidt, 1982a). In the continental U.S., it has been reported from Michigan (Wujek and Hamilton, 1972) and Arizona (Gretz et al., 1979). It occurred in the Sink Hole, Hillsborough River and lower Lake Myakka.

M. caudata Kreiger Figs. 17-18. This species is characterized by a more or less rectangular hole in the posterior portion of the scale. *M. caudata* is widespread in temperate and arctic regions, especially eutrophic and dystrophic lakes. This species, found in the Sink Hole, Myakka River, lower Lake Myakka and Sanabel Island ditch, represents the seventh report for the U.S.

M. crassisquama (Asmund) Fott Figs. 19-20. Electron micrographs of scales of this species were first described by Asmund (1959) from Dannish phytoplankton. Since that time, further micrographs from other countries have shown this species to be cosmopolitan. I collected it from the Sink Hole, Kansas City ponds, and Lake Brooklyn.

M. cristata Durrschmidt Fig. 21. Recently described from Chile (Dürrschmidt, 1981), this represents its first record for North America. Scales were first illustrated, but not identified, as occurring in a rice field in Japan (Takahashi, 1959). The Chilean material represented collections from swamps colored by humic acids, but nitrate and phosphate levels were indicative of oligotrophic conditions (Dürrschmidt, 1981). Loose scales of *M. cristata* were found in 1 Lake Brooker sample.

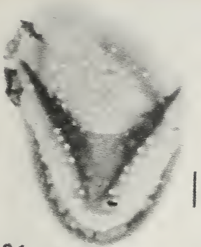
M. cyathellata var *kenyana* Wujek and Asmund Fig. 23. This variety was originally described from Lake Naiwasha, Kenya (Wujek and Asmund, 1979). My collections from the Sink Hole in late March contained scales of this taxon. No cyathi were observed although they are present in the type species, *M. cyathellata*.

M. mangofera Harris and Bradley Fig. 22, 33. Reported from a number of European and Asian localities (Wee, 1982), it has been reported only once from North America (Wujek et al., 1981a). It was found in the Sink Hole, upper Lake Myakka and the Myakka River.

M. portae-ferreae Peterfi and Asmund Fig. 29. The collections from Lake Myakka contained scales of this species. It was recently reported from North America (Wujek and Weis, 1984). Kristiansen (1980, 1981) has indicated this species to have a distinct temporate southern distribution.

M. pseudocoronata Prescott Figs. 24-26. A species of striking appearance under the light microscope, it has never been recorded from outside North America. Its presence in collections made from the Sink Hole, Lake Thonotosassa, Lake Brooker, and 2 Winter Haven ponds represents its most southern occurrence in North America.

M. striata var. *serrata* Harris and Bradley Figs. 27-28. The scale morphology presented here compares favorably with that in the literature. This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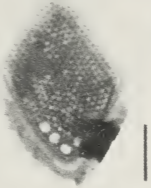
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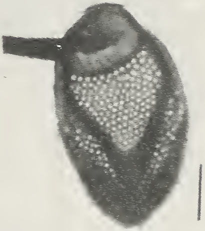
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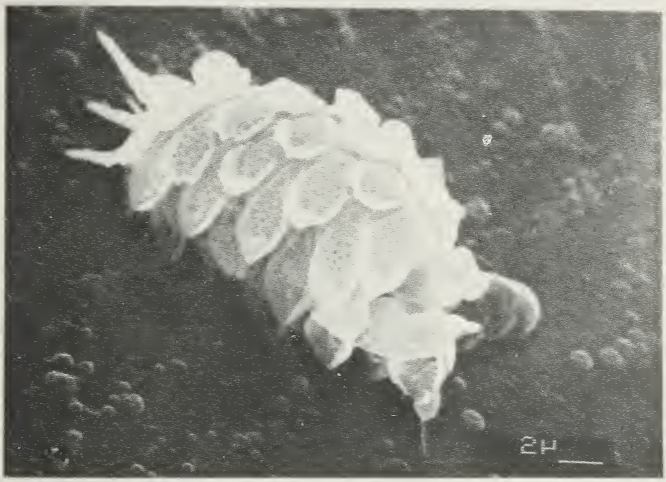

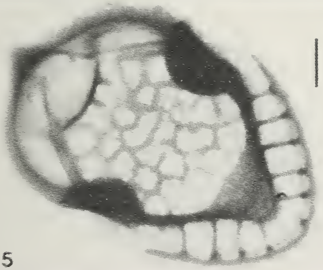
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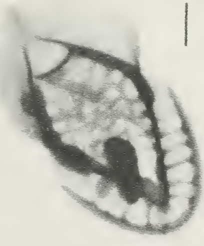
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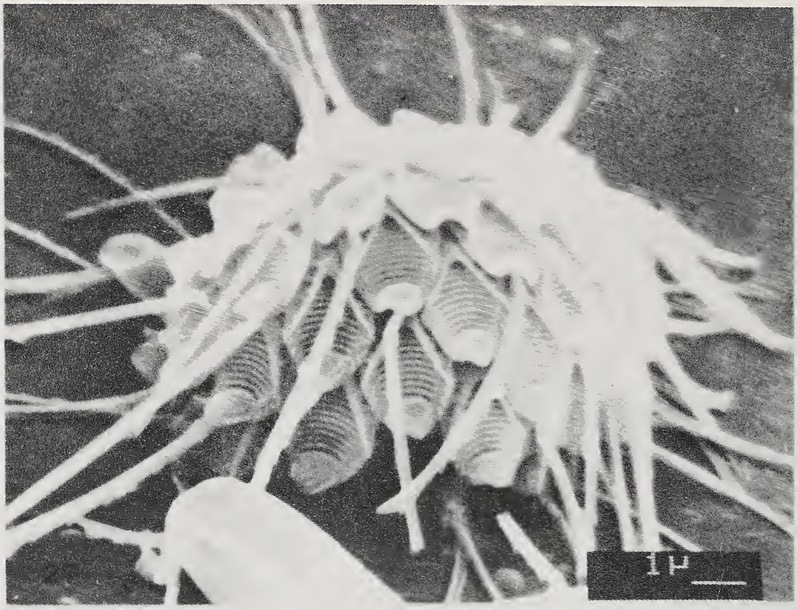
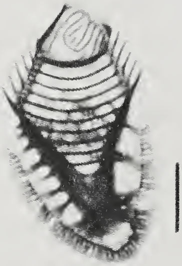
FIG. 21. *Mallomonas cristata*. Fig. 22. *M. mangofera*. Fig. 23. *M. cyathellata* var. *kenyana*. Figs. 24-26. *M. pseudocoronata*. Scale bar = 1 um unless indicated otherwise.





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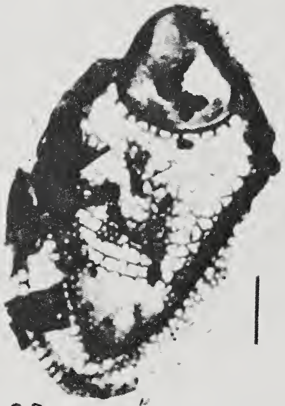

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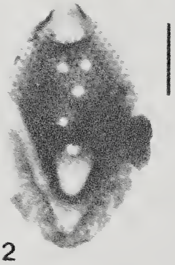

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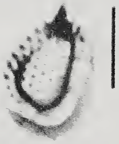

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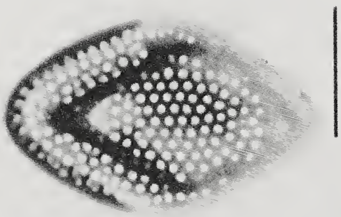

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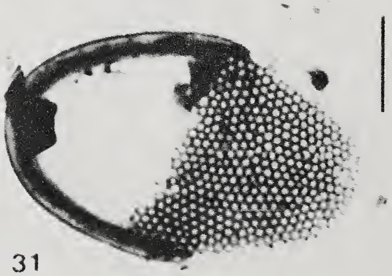

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Figs. 27-28. *Mallomonas striata* var. *serrata*. Fig. 29. *M. portae-ferreae*. Fig. 30. *M. tonsurata*. Fig. 31. *Mallomonopsis elliptica*. Fig. 32. *M. parvula*. Fig. 33. *M. mangofera*. Scale bar = 1 um unless indicated otherwise.

variety differs from the nominate variety by possessing smaller cells and serrate, rather than furcate bristles. In Florida, this species was found in the Sink Hole and lower Lake Myakka.

M. tonsurata Teiling Em. Krieger Fig. 30. There have been only 2 previous reports of *M. tonsurata* from North America including the U.S. (Nicholls, 1982). Loose scales were found in the Sink Hole and Lake Thonotosassa collections.

Mallomonopsis is separated from *Mallomonas* on the basis of possessing 2, long subequal flagella, while the latter has 1 long and 1 very short flagellum. Wujek and Timpano (1984) have recently assembled its previously published worldwide records and occurrence in the U.S.

M. elliptica Matv. Fig. 31. The most widely reported taxon within this genus, I observed scales of it from the Sink Hole samples.

M. parvula Durrschmidt Fig. 32. While having been widely illustrated by numerous investigators (Durrschmidt, 1982b), it has only recently been named. My observations of loose scales and several intact cells from Lake Brooker, upper Lake Myakka and the K.C. Royals' ponds represent its third report in the United States.

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COMPARISON OF FOOD HABITS IN TWO NORTH FLORIDA BLACK BEAR POPULATIONS

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Abstract: *Comparison of black bear diets in fall indicated a less diverse habitat in Osceola National Forest than in Apalachicola National Forest. Although saw palmetto* (Serenoa repens) *was the most important food item in Osceola, it was insignificant in Apalachicola diets. A palmetto mast failure would have minimal impact on Apalachicola National Forest bears, but could cause an energetic hardship on bears in Osceola National Forest.*

Throughout its range, the black bear *(Ursus americanus)* is recognized as an opportunistic omnivore, utilizing a variety of food sources for its nutritional needs (Jonkel, 1978). Often, 1 species dominates a mostly plant diet (Bennett et al., 1943, Hatler, 1972, Landers et al., 1979, Beeman and Pelton, 1980). In Florida, anecdotal evidence points to the importance of saw palmetto *(Serenoa repens)* berries in determining reproductive success. In addition, hunters claim that an abundant palmetto berry crop concentrates bears in uplands and improves hunting success. Indeed, saw palmetto berries account for over 70% of the fall diet in Osceola National Forest (Maehr and Brady, 1982); however, the abundance of this species and lack of other mast producers may be an artifact of modern timber and range management.

Recent studies of black bear food habits in Florida have documented temporal and geographic variation in diet (Maehr and Brady, 1984). Because of the importance of management in the legally-hunted populations of Osceola National Forest and Apalachicola National Forest, a proper understanding of food habits is necessary. In other parts of the black bear's range the distribution and abundance of foods, particularly in fall, influences reproductive success, over-wintering health, and movements (Rogers, 1976, Beeman and Pelton, 1980).

Apalachicola and Osceola National forests are important black bear population centers in North Florida. Hunters of these populations generally agree that the presence or absence of saw palmetto berries directly affects bear feeding behavior. We examine the relationship between saw palmetto berry production and fall food habits of bears in north Florida.

Study Area and Methods—The 249,920 ha Apalachicola National Forest is dominated by a variety of pineland systems in association with bogs, rivers, and savannahs (Clewell, 1971). Longleaf pine *(Pinus palustris)* and saw palmetto often dominate pinelands, while cypress *(Taxodium distichum)*, black gum *(Nyssa sylvatica)* and titi *(Cliftonia monophylla)* are abundant in wetlands. The 63,651 ha Osceola National Forest is characterized by a mixture of slash pine—saw palmetto flatwoods, and black gum and cypress swamps. Both national forests are interspersed by a variety of mesic and xeric oak *(Quercus* spp.) uplands.

Stomachs were collected from hunter harvested bears or road kills each fall (September-December) during 1977-1982. Specimens were frozen shortly after collection or preserved in 95% alcohol or 10% formalin. Stomach contents were washed thoroughly over a series of wire mesh screens before individual food items were segregated. Volume measurements by water displacement were made to the nearest cc in graduated cylinders. Data were analyzed using the aggregate volume and aggregate percent methods described by Martin et al. (1946). Sorenson's similarity coefficient (Greig-Smith, 1964:137) was used to quantify the amount of diet overlap between study areas. The expression $[2c/(a+b)] \times 100$, where a and b are the number of food items consumed in each area, with c the number of food items common to both regions represents a percentage of the number of foods common to each region. Shannon-Weaver indices of diversity (Shannon and Weaver, 1963) were calculated using aggregate percentages of identified foods accounting for more than 3% of the stomach volume in each study area.

Results and Discussion—It has been suggested that winter burning in both national forests has artifically increased the abundance of saw palmetto, while reducing other mast producers (Clewell, 1971:77, Maehr & Brady, 1982). Despite a similar burning regime in the 2 study areas, food habits of the respective bear populations appear quite different (Table 1). The Sorenson similarity coefficient of 61.5 does not seem to be particularly low; however, when the relative volumes of the 4 shared species are examined the divergence of food habits becomes more evident. The 2 plant species occuring in stomachs from both study areas account for 74% of the volume in Osceola National Forest and 55% of the volume in Apalachicola National Forest. Similarly, the 2 shared animal species exhibit higher volumes in Osceola National Forest. In terms of volume and frequency of food items, the Apalachicola sample had higher diversity and evenness than the Osceola sample (Table 1). Implicit in these comparions is that a few species dominate the fall diet of black bears in Osceola National Forest while a greater number of species are used more evenly in Apalachicola National Forest.

We have suggested (Maehr and Brady, 1982) elsewhere that the relatively high occurrence of animal tissue in the diet of bears from Osceola National Forest is in response to a low quality plant food supply. Further, the low frequency of saw palmetto in stomachs from Apalachicola and its overwhelming dominance in Osceola suggests either a difference in food preferences or a difference in habitat quality. It is our assertion that this difference is related to habitat quality and diversity.

To test this conclusion, stomach contents from 1981, in which abundant crops of saw palmetto occurred on both study areas, were examined separately (Table 2). In Osceola, 100% of the stomachs contained saw palmetto berries as compared with only 8% in Apalachicola. The disparity in volume was even more pronounced, with palmetto berries accounting for less than 3% of the volume in Apalachicola bear stomachs. These data suggest that saw palmetto is avoided or is only used as an emergency food (Ripley et al., 1962) by bears in Apalachicola National Forest, whereas it serves as a major food source for bears in Osceola National Forest. If true, it follows that Apalachicola bears are unlikely to suffer from periodic palmetto berry mast failures, but in times of palmetto mast shortage, bears in Osceola National Forest

TABLE 1. Fall foods of black bears in north Florida, 1977-1982.

	Osceola National Forest (n = 35)			Apalachicola National Forest (n = 19)		
Food Items*	Aggregate Percent	Aggregate Volume	Frequency	Aggregate Percent	Aggregate Volume	Frequency
Saw Palmetto (*Serenoa repens*) (berries)	61.0	72.1	27	7.4	6.0	3
Black gum (*Nyssa biflora*)	12.3	5.8	11	47.6	51.5	13
Ordorless bayberry (*Myrica inodora*)				21.2	14.3	11
Acorns (*Quercus* spp.)				7.6	9.4	3
Yellow jackets (*Vespula* spp.)	7.2	7.7	12	3.1	2.4	4
Palm heart fibers (*S. repens*, *Sabal palmetto*)				4.7	7.3	4
Gallberry (*Ilex glabra*)	5.2	3.3	5			
Armadillo (*Dasypus novemcinctus*)	5.0	4.3	7	3.9	5.7	1
Wild hog (*Sus scrofa*)	2.4	3.4	1			
Total	93.1	96.6	—	95.5	96.6	—
H′	1.15	.96	1.49	1.47	1.47	1.69
J′	.64	.53	.83	.75	.75	.89

*Food items represent at least 3% of the total of either aggregate percent or aggregate volume measurements.

TABLE 2. Fall foods of black bears in Osceola and Apalachicola national forests, 1981.

Species[1]	Aggregate Percent	Aggregate Volume	Frequency
Osceola National Forest[2]			
Saw palmetto (*Serenoa repens*)	82.0	82.4	6
Wild Hog (*Sus scrofa*)	14.0	14.7	1
Apalachicola National Forest[3]			
Black gum (*Nyssa biflora*)	75.9	75.9	11
Odorless bayberry (*Myrica inodora*)	12.1	7.7	6
Yellow jacket (*Vespula* spp.)	5.3	4.1	4

[1] Species that account for at least 3% of aggregate percent or aggregate volume.

[2] n = 6 stomachs.

[3] n = 11 stomachs.

would be forced to expend greater energy searching for other available plant foods or actively pursuing animal prey. This potential energy drain could have adverse impacts on over-wintering survival or reproductive success of that population.

The above results indicate the importance of habitat and plant diversity to black bears. Clearly, bears do not wander randomly or evenly throughout their habitat in search of food. Further, because plant foods are not randomly distributed, a direct comparison between the diversity and evenness of foods in bear stomachs and habitat diversity is not necessarily valid. However, we suggest that the diversity of habitat must be at least what is represented in the stomach analyses, and thus, these measurements can be used as an index to relative minimum habitat quality.

If, in fact, the diversity of food resources is limited in Osceola National Forest, the effect of forest management practices on bear habitat should be examined further. Methods for restoring or creating an increased food supply should be tested in order to minimize the impact of forest management on black bears in north Florida and, in particular, to reduce the dependence of Osceola National Forest bears on a single species. Further, mast resources in these 2 important bear population centers should be monitored annually to develop skills in predicting fall mast availability. Harvest strategies could then be altered according to this changing environmental pressure. Finally, a more comprehensive study of the relationship between habitat quality and diversity in the diet of black bears is warranted. Documentation of the relationship between variation in mast production and environmental influences such as rainfall, temperature, and fire would further improve long-range predictive skills.

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DIGESTIVE EFFICIENCIES OF THE WEST INDIAN MANATEE *(TRICHECHUS MANATUS)*

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Abstract: *Digestive efficiencies and consumption rates were determined for a West Indian manatee consuming water hyacinths* (Eichhornia crassipes) *and lettuce* (Lactuca lactuca). *The manatee's estimated* in situ *consumption rate of water hyacinths was low for a mammal of its size, but consistent with its very low metabolic rate. The relatively high digestive efficiencies observed in this study (approximately 80% for water hyacinths and 90% for lettuce) were attributed to the low crude fiber content of plants consumed, the manatee's long retention time of forage, and its extensive intestinal tract. In contrast to other large herbivores, the manatee's consumption/digestion strategy may be characterized by slow consumption and passage rates and postgastric digestion of highly digestible forage.*

The Sirenians (manatees and dugongs) are the only totally aquatic, herbivorous mammals in existence. Because of their special niche, there is much interest in the feeding ecology of these mammals. Although recent studies have contributed to the understanding of feeding behavior of manatees in particular (Powell, 1978; Hartman, 1979; Bengtson, 1981; Reynolds, 1981), little if any information is available on their consumption rates and digestive efficiencies. We estimate consumption rates and digestive efficiencies, and comment on the feeding/digestion strategy of the West Indian manatee *(Trichechus manatus)*.

Methods—Consumption rates and digestibilities were estimated for lettuce *(Lactuca lactuca)*, a common food of captive manatees, and water hyacinths *(Eichhornia crassipes)*, a natural forage of both the Amazonian manatee *(T. inunguis)* and the West Indian manatee (Bengtson, 1981). Feeding trials were conducted during spring 1976 using an adult female manatee (360 kg) held in a large tank (110 m^3) at Marineland of Florida, near St. Augustine. The manatee was fed only lettuce during these studies. Feeding trials for water hyacinths ($N = 3$) were preceded by 6-da adjustment periods during which the manatee was fed only water hyacinths. Passage rate of water hyacinths through the intestinal tract was 146 hr (approx. 6 da) and was marked by a rapid and distinct change in fecal color and composition. Accordingly, daily consumption rates used to estimate digestive efficiences were calculated as the average daily consumption over the previous 6 days. No adjustment period was necessary for lettuce feeding trials ($N = 5$) because there was no change in diet.

During feeding trials (including adjustment periods), the manatee was isolated in a small holding tank (25 m^3) adjacent to the larger one and fed for the first 6 hr (1800 to 2400 hr) of each 24-hr trial. Plants to be fed to the manatee were air-dried until free of loose water, sampled for later determination of dry weight, and weighed to the nearest 10 g. To minimize losses due to mineralization during feeding trials, feces were collected at least every 4 hr; preliminary studies indicated that less than 5% of the feces was lost due to mineralization in an 8 hr period. During the last 10 hr of each 24-hr trial, when most defecation occurred, feces were collected at least every 2 hr.

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All samples of plants and feces were refrigerated prior to laboratory analyses. They were then oven-dried at 65 C until weight loss ceased, and were weighed. Total nitrogen was determined by the Kjeldahl method, and phosphorus was analyzed colorimetrically after digestion with ascorbic acid (A.P.H.A., 1971). Caloric content was measured with a bomb calorimeter. Digestive efficiency was calculated as assimilation (consumption minus excrement) divided by consumption. (See Lomolino, 1977, for a more detailed description of these methods.)

CONSUMPTION AND PASSAGE RATES—*In situ* consumption rates of manatees may be estimated on a time-activity basis given the feeding rate of manatees and the total time manatees spend feeding per day. The mean dry weight consumption rate of water hyacinths by the manatee in this study (during continuous feeding) was 0.48 kg/hr (N = 15, S.D. = 0.07). Because adult manatees normally feed 6-8 hr/da (Hartman, 1979), the estimated *in situ* consumption rate of water hyacinths by an adult manatee is 2.88 to 3.84 kg/da–dry weight, or 43.0 to 57.3 kg/da–fresh weight.

The manatee's consumption rate is very low for a mammal of its size and is even less than that of ruminants, which have characteristically low weight specific consumption rates (Table 1). However, this low consumption rate is consistent with the relatively low metabolic rate of the manatee, which is approximately 60% of that expected for a mammal of its size (Scholander and Irving, 1941).

Similarly, the passage rate of water hyacinths through the manatee's digestive tract is quite slow, especially for a nonruminant (Table 1). This slow passage rate may be accounted for, at least in part, by the manatee's long intestinal tract [length of large intestines = 18 m in the manatee (Quiring and Harlan, 1953) vs. 10, 8, and 4 m in cattle, horses, and sheep, respectively (Sisson, 1953)].

DIGESTIVE EFFICIENCY—The digestive efficiency exhibited by an herbivore is primarily determined by its digestive physiology and the composition of plants it consumes. For a given herbivore, digestibility should be inversely correlated with the crude fiber content of plants consumed (Church,

TABLE 1. Consumption and passage rate of the manatee, 2 other nonruminants [the elephant *(Elaphus maximus)* and horse *(Equus caballus)*], and 2 ruminants (Murrah buffalo and Hariana cattle *(Bos bubalis* and *B. tairis)).*

Herbivore	Forage	Consumption rate[a] (g/da·kg)	(g/da·kg^{75})	Passage rate (da)
Manatee	water hyacinths	9	41	6.0,5.0[b]
Murrah buffalo[c]	wheat	20	77	3.8
Hariana cattle[c]	wheat	22	87	3.3
Horse[d]	timothy	29	83	2.5[e]
Elephant[f]	timothy	13	97	2.3

[a] Consumption rate expressed in dry matter per metabolic body weight (kg^{75}) to adjust for effects of body size on energy requirements.

[b] Best, 1981.

[c] Ponnappa et al., 1971.

[d] Darlington and Hershberger, 1968.

[e] Vander Noot et al., 1967.

[f] Benedict, 1936.

1970). Consistent with this, the digestive efficiency of the manatee for lettuce (crude fiber content 10-12%; Bowes and Church, 1966) was considerably higher than that for water hyacinths (12-17%; Shirley and Easley, 1970; Taylor and Robbins, 1968) (Table 2). Because other aquatic plants (freshwater plants and seagrasses) have crude fiber contents similar to that of water hyacinths (Linn et al., 1975; Wake, 1975; Murray et al., 1977), the digestive efficiencies for water hyacinths reported in this study (approx. 80%) may be representative of digestive efficiencies of the manatee for natural forage in general.

TABLE 2. Digestive efficiencies of the manatee (assimilation as percent consumption) for water hyacinths and lettuce (standard deviations included in parentheses).

Food	Dry weight (%)	Energy (%)	Nitrogen[1] (%)	Phosphorus (%)
Water hyacinths	82.6(1.7)	80.0(2.1)	78.1(2.2)	82.0(2.5)
Lettuce	91.4(1.4)**	88.8(1.9)*	93.8(1.0)**	79.3(3.2)

[1] Digestive efficiency for nitrogen is equivalent to that for crude protein.
*$P < .025$, **$P < .01$; Student's t-test.

In comparison to other large herbivores, digestive efficiencies of the manatee are quite high, especially considering the manatee's postgastric (nonruminant) digestive system. In fact, digestive efficiencies of the manatee for natural forage exceed those of ruminants (e.g., sheep and cattle) by 10 to 20%. One reason for this is the relatively low fiber content of aquatic plants, which is roughly half that of terrestrial plants (20 to 40%; Church, 1972). In addition, the manatee's relatively low consumption and passage rates and long intestinal tract (see Quiring and Harlan, 1953; Lemire, 1968; Reynolds, 1980) are important factors contributing to its high digestive efficiency, the latter providing a much greater surface area for absorption (see also Best, 1981).

In summary, the manatee's (and perhaps, in general, Sirenian's) feeding/digestion strategy may be characterized by slow consumption and passage rates and postgastric digestion of highly digestible forage. This strategy is quite distinct from that of ruminants (pregastric digestion and slow passage rates) and terrestrial nonruminants (postgastric digestion, but with rapid consumption and passage rates; see Janis, 1976), but one that is well adapted to the totally aquatic, herbivorous niche of these Sirenians.

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MANATEE USE OF POWER PLANT EFFLUENTS IN BREVARD COUNTY, FLORIDA

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Abstract: *The relationship between manatees and power plants was investigated at 2 power plants on the Indian River in Brevard County, Florida from January 1978-February 1980. Manatee presence in the power plant effluent zones was correlated with cold air and water temperatures. When air temperatures were below 16°C most manatees in the county were found in the effluent zones. Manatees in the effluent zones moved with the wind-blown warm water plume, demonstrating a sensitivity to small changes in water temperature. Some individuals were frequently resighted at 1 plant, while others moved between the 2 plants. Because industrial warm water sources are less reliable than natural warm water refuges, it is recommended that no new artificial warm water effluents be constructed north of the species' traditional winter range.*

The West Indian manatee *(Trichechus manatus)*, an herbivorous marine mammal, seeks refuge from cold winter waters in Florida by migrating south (Shane, 1983a) or moving into natural warm springs (Hartman, 1979; Powell and Waldron, 1981) or industrial warm effluents (Hartman, 1974; Irvine and Campbell, 1978; Rose and McCutcheon, 1980; Shane, 1983a). Most manatees found in Brevard County on Florida's central east coast (Fig. 1) in January and February are observed in the effluent zones of 2 power plants: Florida Power and Light Co. Canaveral Plant (FPL) and Orlando Utilities Commission Indian River Plant (OUC) (Shane, 1983a). Although the fact that manatees use industrial warm water effluents as winter refuges is well-documented, the details of that relationship have not been investigated previously. I describe the relationship between manatee distribution in the power plant effluents and environmental factors, and discuss the effects of warming trends on manatee use of the effluent zones.

Description of Study Area—Manatee distribution, abundance, and behavior were monitored at the FPL and OUC plants and throughout Brevard County from January 1978 through February 1980 (Shane, 1983a, 1983b). FPL and OUC are oil-burning electrical generating plants located 3 km apart. Both plants have once-through cooling systems that draw Indian River water through their intake structures and discharge it into the river after heating it approximately 5-6°C above ambient temperature. FPL has 2 effluent units and OUC has 1 effluent canal where the heated water is discharged. The term "effluent zone" refers to the area accessible to manatees at each plant where water temperatures are increased over ambient river temperatures.

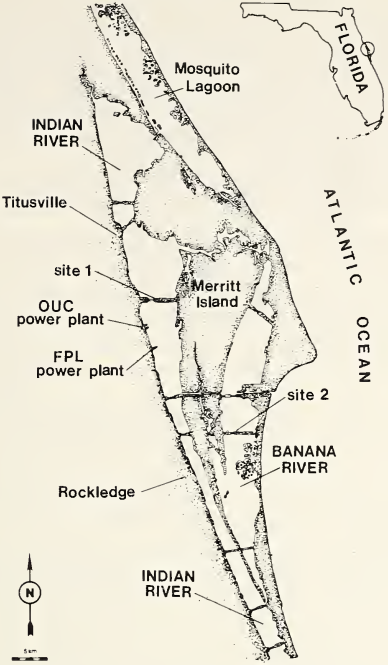

FIG. 1. Location of the Florida Power and Light Co. (FPL) and Orlando Utilities Commission (OUC) power plants on the Indian River in Brevard County, Florida. Site 1 is where Indian River temperatures were collected, and site 2 is where Banana River temperatures were recorded.

METHODS—To document the relationship between manatee distribution and temperature, surface water temperatures were collected in the intake canals and at stations throughout the effluent zones of the 2 power plants. Temperatures were recorded at FPL almost daily from January-March 1978, 1 to 4 times per month from April-September 1978, and at both FPL and OUC 1 to 10 times per month from October 1978 to October 1979. Temperature collections were reduced during warm months when manatees were absent from the effluent zones and after the general temperature distribution pattern was established in winter 1978. Temperatures were taken at depths of 5-15 cm using a thermistor probe trailed overboard as the boat idled through the effluent zone (Yellow Springs Instrument Co. [YSI] Model 33 S.C.T. or YSI Model 44TD). Ambient Indian River and Banana River temperatures were recorded at 2 sites 2 to 5 times per month (Fig. 1). Mean monthly river temperatures were compiled from these data.

Manatee abundance and distribution were determined by conducting aerial surveys in a Cessna 172 flown at altitudes of 150-185 m and speeds of 130-140 km/h. Two observers usually participated. Data from 2 survey areas are considered here: 1) the Indian River from Titusville to Rockledge (excluding the effluent zones) and the Banana River; and 2) the effluent zones. The Indian and Banana rivers were surveyed biweekly year-round, and the flight path included likely manatee habitat as well as known areas of manatee concentration. Surveys covering the effluent zones (including the area within 5 km of them) were flown 1 to 7 times per month from October 1978-April 1979 and from November 1979-February 1980. The flight path on these surveys included east-west transects across the Indian River and circles of the plants to effect total coverage of the area.

Observation conditions were subjectively determined to be poor, fair, good, or excellent following each aerial survey. Factors affecting survey conditions included wind, cloud cover, water turbidity, glare, and manatee behavior. Only data collected under good to excellent conditions or maximum counts (usually made on days with good or excellent conditions) were used in the analyses, because these totals were believed to be the most accurate. Minimum air temperatures used in the analysis of aerial survey data were collected on Merritt Island by the Patrick Air Force Base Climatological Group.

Manatee behavior was observed from a boat (5 m Boston Whaler or 7 m Wellcraft) or from shore. Individual manatees were identified by scar patterns (Hartman, 1979).

RESULTS—Up to 106 manatees were recorded in the FPL and OUC effluent during the 3 winters covered by this study (Shane, 1983a). The number of manatees in both effluent zones combined was inversely correlated with minimum air temperature ($r = -0.73$, $P<0.01$; data from 21 effluent zone aerial surveys). In turn, Indian River temperatures were significantly correlated with minimum air temperatures ($r=0.81$, $P<0.01$; $N=46$).

During the winter, cold fronts and warming trends were expected to affect manatee use of the effluent zones. The direct effect of individual cold fronts on manatee abundance in the effluent zones could not be determined. Rough, turbid waters caused by winds associated with cold fronts resulted in poor or fair survey conditions and prohibited accurate counts of manatees in the effluent zones. The effect of winter warming trends on manatee use of the effluent zones was easier to determine. Manatee abundance decreased in the effluent zones and increased outside them in response to rising air temperatures ($X^2=252.1$; $P<0.005$) (Table 1). Manatees responded to temperatures warming both during the course of 1 da and over a period of a few days. Manatees that dispersed from the effluents during warm spells usually remained near the power plants. They frequently traveled to the eastern shore of the Indian River opposite the power plants where seagrasses grew sparsely.

TABLE 1. Number of manatees sighted in the FPL and OUC power plant effluent zones or outside the effluent zones but within 5 km of the power plants at different minimum air temperatures. Data were taken from effluent zone aerial surveys conducted under good to excellent conditions.

Minimum air Temp. (°C)	Number in Effluents	Number outside Effluents	N
6-10°	319	75	394 manatees on 5 flights
11-15°	510	208	718 manatees on 9 flights
16-20°	77	221	298 manatees on 7 flights

$X^2=252.1$; $P<0.005$

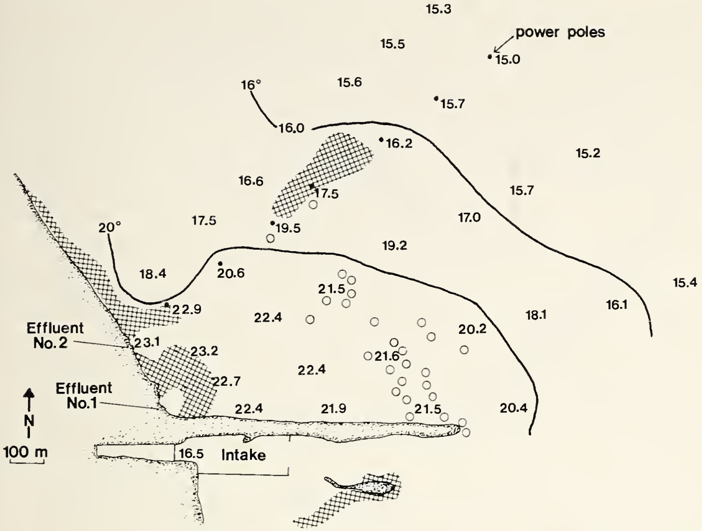

FIG. 2. Location of the warm water plume and the manatee aggregation (open circles) in the FPL effluent zone on 22 da with north winds in excess of 10 mph in January-March 1978. Water temperatures (°C) are mean values for those 22 da. Cross-hatched areas are shoals < 1 m in depth.

Rather than dispersing randomly, manatees within the effluent zones usually formed 1 large, loosely associated aggregation, the distribution of which was related to depth and water temperature. At OUC, manatees avoided shoals < 1 m deep and were restricted to a relatively narrow channel extending outward from the effluent canal. Manatees usually avoided shoals at FPL also (Fig. 2-3). However, on warm days, manatees on the periphery of the aggregation moved onto the edges of the shoals to rest or engage in social behavior; solar radiation probably warmed the shallow water on such days. On cold days manatees generally remained in the deeper parts of the effluent zones, because shallow waters presumably cooled more rapidly. Manatees responded to relatively small changes in water temperature by following the movement of the warm water plume in the FPL effluent zone. This sensitivity to changes in water temperature was best demonstrated by the shifting of the warm water plume and of the manatee aggregation at FPL on days with strong north (Fig. 2) or south (Fig. 3) winds.

Opportunistic sightings of recognizable individuals showed that some manatees moved between the FPL and OUC effluent zones during the winter. Three individuals were seen in both effluent zones. One was seen at the FPL effluent in December 1979 and in the OUC effluent in February.

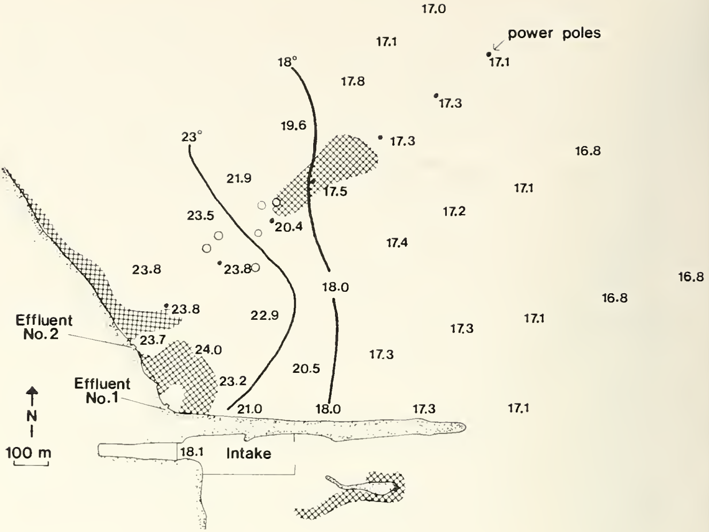

Fig. 3. Location of the warm water plume and the manatee aggregation (open circles) in the FPL effluent zone on 6 da with south winds in excess of 10 mph in January-March 1978. Water temperatures (°C) are mean values for those 6 da. Cross-hatched areas are shoals < 1 m in depth.

1980. The other 2 were seen in the FPL effluent in December 1979 and in the OUC effluent in January 1980. Two additional manatees were sighted between the 2 power plants in December 1979 and in the OUC effluent zone in January and February 1980.

Twelve manatees were each sighted in the OUC effluent zone more than once (range = 2-6). Of these, 2 individuals returned to the OUC effluent zone for 2 winter seasons (1978-79 and 1979-80). Because manatees were difficult to identify at FPL, little information was gathered on individuals using that effluent zone.

While manatees gathered in the effluent zones to take advantage of the warm water, they engaged in resting, social interactions, and feeding. No seagrasses grew in the effluent zones, but algae were abundant there. Several manatees fed on red algae (*Gracilaria* sp.) on one occasion at OUC, and 1 manatee ate green algae growing on the wall of effluent no. 2 at FPL.

Discussion—Decreases in air and water temperatures were significantly correlated with increases in the number of manatees in each effluent zone. The correlation between air and water temperature in this study made it impossible to determine which factor was more important in motivating manatees to enter the effluent zones. Air temperatures below 16°C in Brevard County were associated with a majority of the animals within 5 km of the plants moving into the effluent zones (Table 1). Moore (1956) observed that air temperatures below 10°C were associated with manatees gathering in a power plant effluent in Miami. In the present study water temperatures below about 21°C corresponded with large aggregations of manatees in the effluent zones. Hartman (1979) reported that manatees began to enter Crystal River, a warm spring on Florida's west coast, when Gulf temperatures dropped below the spring's constant 23.7°C.

The dispersal of manatees onto grassbeds along the eastern shore of the Indian River where they probably fed during winter warm spells indicated that manatees would leave the effluents when temperatures permitted. During prolonged cold spells, however, manatees may be restricted to the effluent zones where there is no vascular vegetation. If so, they must either feed on algae or cease feeding temporarily. Hartman (1979:44) indicated that manatees "resorted to" eating algae only when vascular vegetation was unavailable. Campbell and Irvine (1981) cited evidence that manatees may feed irregularly at water temperatures of 18-19°C and may stop feeding at 16°C and below.

Manatees exhibit a high degree of sensitivity to differences in water temperature. By moving with the warm water plume in the FPL effluent zone (Fig. 2-3), manatees demonstrated an awareness of fairly small changes in water temperature and showed a preference for the slightly warmer water.

An exchange of manatees between the 2 plants occurred, although it is possible that some individuals used only 1 effluent zone during a given winter. The sighting of 2 manatees during 2 consecutive winters at the OUC effluent zone is consistent with findings that manatees return to the same winter refuges year after year (Moore, 1956; Powell and Waldron, 1981; Hartman, 1979; Shane 1983b).

Artificial sources of warm water in Brevard County and Jacksonville (Hartman, 1974) have allowed manatees to expand their winter range beyond its historical limits (27°52'N; Moore, 1951). Such an expansion could contribute to increased manatee abundance in Florida by providing additional habitat. Already, up to 10% of the minimum estimated Florida population of manatees (Campbell and Powell, 1976) uses the Brevard County power plants for winter shelter. However, winter habitat is being altered in southern Florida due to human development, and the enlarged winter range may not compensate for habitat loss elsewhere.

The most serious disadvantage of artifical warm water sources is their lack of reliability. Whereas natural springs maintain a constant temperature year-round, data from this study show that artifical effluent temperatures are dependent upon ambient water temperatures and can decline to levels that may be harmful to manatees. Severe cold spells are known to be associated with manatee deaths (Bangs, 1895; Cahn, 1940, Krumholz, 1943; Layne, 1965), and during the unusually cold winter of 1976-77, 22 manatee deaths in Brevard County were presumed to have been cold-related (Campbell and Irvine, 1981). The OUC and FPL effluents may not have been warm enough to protect manatees that winter. In addition, the possibility of temporary or permanent power plant shut-downs compounds the risk faced by manatees relying on artificial warm water refuges.

Until further information is available on the positive and negative effects of artificial effluents on manatee populations, I must reiterate the position taken by participants in the West Indian Manatee Workshop (Brownell and Ralls, 1981): no new artificial warm water effluents accessible to manatees should be created north of the species' historical winter range limits.

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IMPLICATIONS OF THE PRESENCE OF MANATEES (*Trichechus manatus*) NEAR THE DRY TORTUGAS ISLANDS

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ABSTRACT: *Two West Indian manatees (*Trichechus manatus*) were observed 61 km northeast of the Dry Tortugas Islands, a location not normally considered to be part of the species' range. When spotted, the animals were swimming in a southwesterly direction, away from Florida. Observations such as this, of manatees far from freshwater, raise the question of whether manatees require regular access to freshwater for osmoregulation, as suggested in the literature.*

ALTHOUGH Odell (1982) states that the exact distribution of the West Indian manatee (*Trichechus manatus*) is unknown, Moore (1951) and Hartman (1974; 1979) have suggested that the species is restricted to regions where freshwater is available for osmoregulation. It was somewhat surprising, therefore, to find manatees in waters where freshwater is either unavailable or in limited supply.

On 18 January 1982, 2 manatees, each estimated to be at least 3 m long, were observed 61 km northeast of Loggerhead Light in the Dry Tortugas Islands (25°07′ N, 82°37′ W, dead reckoning). The animals were spotted from an 11.5 m sailboat, and they were swimming in a southwesterly direction about 0.5 km apart from one another. Water depth at the sighting locations was approximately 41 m. No photographs were obtained, but the distinctive appearance of the manatee makes misidentification difficult.

Our manatee sighting constitutes the second reported occurrence of the species in the Dry Tortugas; the first was reported by William Robertson (Everglades National Park biologist) to have occurred in the later 1960s (Hartman, 1974). This group of sand islands is located about 110 km west of Key West, Florida. The Tortugas and the surrounding waters have no known freshwater input other than rainwater. In fact, limited freshwater availability has been suggested as an explanation for the rare occurrence of manatees as far away from the Tortugas as the lower Florida Keys, including

Key West (Hartman, 1974). What, then, could cause manatees to appear in the Dry Tortugas?

One of several explanations could provide an answer. Husar (1977) pointed out that individual manatees have wandered great distances from the more "usual" range in peninsular Florida. Hamilton (1839) even reported that manatees had been found in northwestern Europe and Odell, Reynolds, and Waugh (1978) observed an adult animal in the Bahama Islands. Perhaps the manatees seen in the Dry Tortugas were simply wanderers; possibly, cold weather and turbulence following passage of a very severe cold front on 10 January 1982 (National Weather Service, pers. comm., 1983) could have induced the animals to travel southward. In either case, if long-term lack of freshwater were lethal to manatees, such wanderers would probably not survive; conceivably the Tortugas manatees did not live.

Another explanation for the animals' presence in the Tortugas was that they represented migrants between the manatee population in Florida and those of Cuba or Yucatan. Once again, lack of freshwater during such a prolonged journey could prove lethal to animals that require freshwater.

Finally, it is possible that manatees do not require freshwater for osmoregulation. They may simply prefer occasional exposure to freshwater; a reason for such preference might be to rid themselves of stenohaline ectoparasites or endoparasites. Besides being found in the Florida Keys, manatees have been reported from other locations, such as the Bahama Islands (Odell, Reynolds, and Waugh, 1978), where freshwater is not abundant. Other factor(s) (e.g., shallow waters, lack of vegetation for food, or predation in offshore waters) might be responsible for specific manatee distribution, rather than lack of freshwater for osmoregulation.

The question remains as to West Indian manatees' osmoregulatory capabilities. Whereas the gross structure of the manatee kidney is known, detailed studies of renal physiology and microscopic anatomy (at both the light and ultrastructural levels) are lacking. Such studies must be done to more adequately understand the requirements of this endangered species.

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ALGAL CONSUMPTION BY THE MANATEE (*Trichechus manatus* L.) IN TAMPA BAY, FLORIDA—*Roy R. Lewis, III*, *Jedfrey M. Carlton*, and *Ralph Lombardo*, Mangrove Systems, Inc., P.O. Box 24748, Tampa, Florida 33623; U.S. Army Corps of Engineers, P.O. Box 4970, Jacksonville, Florida 32232; Mangrove Systems Inc., P.O. Box 24748, Tampa, Florida 33623.

Abstract: *In January 1981, 4 to 6 manatees were observed apparently feeding on* Ulva *sp. (green alga) near a shallow sand bar at the mouth of the Alafia River. Plant material was subsequently collected for identification and weight. Algae collected were* Graciliaria tikvahiae *(dominant),* Ulva *sp. and* Chaetomorpha linum. *It is suggested that marine algae may be an important food source for the Tampa Bay winter manatee population. From the available information we were not able to determine whether the manatees were actively selecting* Ulva *on which to feed.*

The manatee (*Trichechus manatus* L.) has been reported to feed on a number of species of both vascular and nonvascular plants (Campbell and Irvine, 1977; Hartman, 1979). In brackish and marine environments in Florida, they appear to favor *Syringodium filiforme* Kutzing when mixed with *Thalassia testudinum* Konig et Sims (turtle grass), but they also consume *T. testudinum*, *Halodule wrightii* Ascherson (shoal grass) and *Ruppia maritima* L. (widgeon grass). "In turbid waterways with impoverished vascular flora, manatees supplement their diet by feeding on algae" (Hartman, 1979).

Methods and Study Area—On 29 January 1981, a group of 4 to 6 manatees was observed surfacing adjacent to a shallow sandbar on the northern side of the ship channel at the mouth of the Alafia River in Tampa Bay. The site previously had been designated by Patton (1980) as one of the areas frequented by manatees.

We observed the manatees from 1030-1100 hr, during which they came very close to our drifting boat. One manatee raised its head completely out of the water with a large clump of green algae in its mouth.

At approximately the same time the next day, the site was revisited. Five haphazard tosses of a 0.25 m × 0.25 m PVC quadrat were made in the shallow (1 m) water where feeding had been observed the previous day, and all plant materials in the quadrat were collected, placed in a plastic bag, preserved with 5% formalin in seawater, and returned to the lab. Samples were separated by species, dried at 105°C for 24 hr, and weighed to the nearest 0.01 g.

Results and Discussion—The results of the submerged aquatic vegetation analysis indicated that only marine algae were present. *Gracilaria* *tikvahiae* was the dominant species present, comprising 95.1% of the standing crop. *Ulva* sp. and *Chaetomorpha linum* composed 4.8% and 0.1% of the samples respectively.

Lewis and Phillips (1980) have previously documented the disappearance of all seagrass meadows from the vicinity of the Alafia River. Federal Water Pollution Control Administration (1969) previously had noted the large standing crops of marine algae in Hillsborough Bay, with *Gracilaria* being the dominant species (98% of the net weight).

Patton (1980) reported that the Alafia River upstream from this site (approximately 2 km), in the vicinity of a small thermal discharge from a phosphate processing plant, had the largest single concentration of manatees seen in that study (39 adults and 3 calves, 7 February 1980). On the same date, 11 adults and 2 calves were seen at our observation site, for a total of 55 individuals. Only 1 adult was observed near a much larger thermal discharge (from a power plant) located 6.4 km south of the Alafia River, on the same survey date. Patton (1980) noted, "no evidence of submerged vegetation in the discharge canal was encountered (hence precluding feeding activities)." Although a power plant shut-down on 4 February 1980 had markedly lowered the discharge canal temperature, manatees were routinely more numerous at the Alafia River. Patton (1980) also noted that: "The only feeding manatees observed during the winter were at the mouth of the Alafia River where unidentified submerged aquatic vegetation appears to be well established in the vicinity of the spoil islands. No manatees were observed feeding in the Big Bend (power plant) area. The food sources and feeding patterns of the Tampa Bay manatee population are unknown."

Our observations and those of Patton (1980) indicate that marine algae are an important food source for the Tampa Bay winter manatee population. It is impossible to determine from our limited observations if the manatees are selectively taking only *Ulva* or the combined mixture of algae. The major concentration of manatees during the winter months at this location appears to be related to both thermal discharge and abundant food. In addition, protection is enhanced by strongly enforced power boat speeds in the area, which has been established as a manatee sanctuary by the Florida Game and Freshwater Fish Commission.

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A RAPID AND PORTABLE METHOD FOR THE DISSOCIATION OF TISSUE FROM THE CORAL SKELETON—*Anthony H. Knap and Thomas D. Sleeter*, Bermuda Biological Station, Ferry Reach 1-15 Bermuda

Abstract: *A method has been developed to remove coral tissue from coral skeleton using high pressure gas. When used with a scuba tank fitted with a single stage pressure regulator and a molecular sieve trap, tissue can be removed from corals at remote sampling sites thus avoiding the transport of bulky carbonate skeleton.*

Our interest in the biology and chemistry of corals and more recently the occurrence of anthropogenic trace organic compounds in coral tissue (Knap et al., 1982; 1983) has led us to re-evaluate current methods of quantitative and qualitative analyses of coral tissue. We report here a simple, portable method for the removal of coral tissue from the coral skeleton that for many types of coral tissue analysis appears to be more suitable than others we have tested. This method also allows the removal of zooxanthellae from *Diploria strigosa* tissue without cellular disruption for productivity studies (Cook and Knap, in press).

The quantitative analysis of material from coral tissue presents some novel problems. The large skeletal mass relative to the coral tissue can make quantification of extracted material difficult. The tissue represents less than 1% of the coral by weight and the ratio of skeletal material to tissue weight increases with the increasing age/size of the coral. This leaves the analyst with the problem of either analyzing the coral tissue and skeleton together or trying to dissociate the tissue from the skeleton.

Our main criteria for the analysis of coral tissue for trace organics of pollutant origin was to avoid large volumes of water as well as to facilitate minimal sample handling. A method previously used for similar work is the Water Pik method, developed by Johannes and Weibe (1970). Although an ideal method for removal of tissue from skeleton for some analyses, the large solution volumes, the possible contamination of the sample by plastic and lubricants and the electrical power requirements made this a disadvantage for our work. Peters et al. (1981) have used a method involving sectioning and grinding of the coral followed by a 3N HC1 acidic digestion of the coral skeleton. The disadvantage there is that there is no separation between compounds in the coral tissue and those that may be present in coral skeleton. We have found that when coral is exposed to petroleum hydrocarbons, oil can adhere to the base of the coral skeleton, thus care must be taken to make the distinction between incorporation by coral tissue and carbonate skeletal adsorption.

Our technique (Fig. 1) uses a 300-600 PSI air or nitrogen stream provided by a Scuba tank and a single 2 stage pressure regulator and a fine bore (1mm I.D.) stainless steel tubing. The end of the tube is flattened to give a broad area and the coral is inverted over a 4L beaker and the tissue removed by gas pressure. The tissue is then scraped into glass vials and transported to the laboratory for analysis. More than 95% of the tissue is routinely removed from the coral. The skeleton is imprinted with aluminum foil to give an estimation of surface area and the compounds analyzed may then be related to total protein, tissue dry- or wet-weight or total skeletal surface area.

The method chosen for coral analysis depends on the type of compound to be determined and certain methods have advantages over others. For the analysis of trace pollutant organics from coral tissue gas removal is a rapid and simple means for the dissociation of tissue from coral skeleton and provides a lower risk of contamination than other methods. By fitting a scuba tank with a molecular sieve trap one can devise a highly portable device for sampling in remote areas, enabling the analyst to sample the tissue on-site and eliminating transport of bulky skeletal material.

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THE SHALLOW-WATER MARINE PELECYPODS OF BERMUDA: AN EXAMPLE OF A SWEEPSTAKES ROUTE—*David Nicol*, Box 14376, University Station, Gainesville, Florida 32604.

ABSTRACT: *Almost all of the 99 species of shallow-water pelecypods now living in Bermuda colonized these remote islands via a sweepstakes route provided by the Florida Current and the Gulf Stream. More than half of these species have a very wide geographic distribution, and 66, or two thirds of the species living in Bermuda, also live in Brazil. Seven of the species living in Bermuda also live in the tropical eastern Pacific. Only 2 species are endemic to Bermuda.*

THE number of shallow-water (less than 250 m) marine benthic species of living pelecypods of Bermuda is at least 99, even if the wood-boring species are eliminated. Waller (1973) stated that the West Indian nature of the marine molluscan fauna of Bermuda has long been known. The reason for this strong West Indian affinity is that the Florida Current and the Gulf Stream sweep northeasterly, transporting the larvae of marine animals from southern Florida and the Bahama Islands toward Bermuda. Because Bermuda is isolated from other areas of land and is surrounded by deep water, the shallow-water marine fauna has been populated by chance as a typical sweepstakes route as defined by Simpson (1940). The basic data on the distribution of the pelecypods of Bermuda were taken primarily from Abbott (1974).

The geographic distributions of the 99 living species of shallow-water pelecypods found in Bermuda can be placed into 10 categories (Table 1). In this regard, the 19 distribution maps of the Caribbean molluscan fauna, given by Warmke and Abbott (1961), are helpful. At least three fourths of the species of pelecypods that have successfully colonized Bermuda have wide geographic distributions, but only 6 Bermuda species have a range north of North Carolina. Seven of the species found in Bermuda also live in the tropical eastern Pacific, and 66 species that live in Bermuda also live in Brazil. On the other hand, only 2 species are found solely in the West Indies and Bermuda. *Erycina linella* Dall has an anomalous distribution because it has been reported only from North Carolina and Bermuda. Of the 99 species of extant benthic marine pelecypods of Bermuda, only 2 appear to be endemic. *Lucina* (*Callucina*) *bermudensis* Dall has been reported solely from Bermuda. The other species is *Tucetona subtilis* Nicol, 1956, a glycymeridid. *Tucetona subtilis* is closely related to *Tucetona pectinata* (Gmelin), which is common and wide-ranging and is found from North Carolina, the West Indies, and Brazil. It appears that *Tucetona subtilis* is a recent offshoot of *Tucetona pectinata*.

TABLE 1. The 10 basic patterns of geographic distribution of the pelecypods of Bermuda with the number of species in each.

Geographic Distribution	No. of Species
1. North or South Carolina, usually Gulf Coast, West Indies, Brazil, Bermuda.	41
2. North Carolina or Florida, Gulf Coast, West Indies, Brazil, Bermuda and tropical eastern Pacific.	7
3. Florida, Gulf Coast, West Indies, Brazil, Bermuda.	15
4. North of North Carolina, Florida, Gulf Coast, West Indies, and sometimes Brazil, Bermuda.	6
5. North Carolina, Florida, Gulf Coast, West Indies, Bermuda.	7
6. Southern Florida, Bahamas and Caribbean, Bermuda.	17
7. West Indies and Bermuda.	2
8. Southeast Florida and Bermuda.	1
9. North Carolina and Bermuda.	1
10. Endemic to Bermuda.	2
Total Number of Species.	99

There are obviously some genera and species of marine benthic pelecypods that are not holders of tickets to the sweepstakes route to Bermuda. These genera and species are confined, or nearly so, to the Boreal and Arctic realms. Some of these non-ticket-holders would include *Yoldia*, *Axinopsida*, *Leptaxinus*, *Turtonia*, *Astarte*, *Serripes*, *Clinocardium*, *Spisula*, *Mesodesma*, *Siliqua*, *Arctica*, *Liocyma*, *Mya*, and *Cyrtodaria*. Another group of non-ticket-holders are those genera and species that are living in the Caribbean region but are not found in the Bahama Islands or southern Florida. Almost all of the species of pelecypods living in Bermuda must have come from these two areas, carried there by the Florida Current and the Gulf Stream. This is borne out by the new arrivals to Bermuda described by Abbott and Jensen (1967) and is clearly illustrated on maps shown in Warmke and Abbott (1961). There are almost no occurrences of disjunct distributions in the bermudian pelecypod fauna, and the fact that there are only 2 endemic species indicate that this sweepstakes route has been in existence for a short time, probably no more than 2 million years.

Sweepstakes routes commonly have 2 characteristics, as Simpson (1940) pointed out: the faunas tend to be unbalanced, and the movement or migra-

TABLE 2. The species of living shallow-water species of pelecypods of Bermuda allocated to family.

Families	No. of Species
1. Nuculidae	1
2. Arcidae	5
3. Glycymerididae	1
4. Mytilidae	6
5. Pinnidae	1
6. Pteriidae	3
7. Isognomonidae	3
8. Malleidae	1
9. Pectinidae	8
10. Plicatulidae	1
11. Spondylidae	1
12. Anomiidae	2
13. Limidae	2
14. Ostreidae	1
15. Lucinidae	8
16. Ungulinidae	1
17. Chamidae	4
18. Lasaeidae	2
19. Sportellidae	2
20. Condylocardiidae	1
21. Crassatellidae	1
22. Cardiidae	8
23. Mesodesmatidae	3
24. Tellinidae	14
25. Psammobiidae	2
26. Semelidae	3
27. Solecurtidae	2
28. Trapeziidae	1
29. Glossidae	1
30. Veneridae	4
31. Petricolidae	1
32. Gastrochaenidae	3
33. Lyonsiidae	1
34. Verticordiidae	1
Total Number of Species.	99

tion of animals is in only 1 direction. Table 2 is a tabulation of the 99 species grouped into 34 families of marine pelecypods. Of the deposit-feeding protobranchs, only 1 species of nuculid is present. This is not unexpected because these pelecypods are most diverse in deep and/or cold water. The Arcidae is represented by 5 species, and considering the diversity of this family, more species would be expected, particularly of *Anadara*, which is represented by a single species. *Glycymeris undata* (Linné) and *Glycymeris decussata* (Linné) may be considered disappointed ticket holders because both of these common West Indian species do not live in Bermuda. The Mytilidae is represented by 6 species in the fauna of Bermuda, and 3 of these species are rock borers. The Pinnidae has 1 species living in Bermuda, but *Atrina*, which is the most diverse genus within the family, is absent. The small families Isognomonidae, Pteriidae, and Malleidae are all well represented in the fauna of Bermuda, and these families are restricted to warm-water habitats. The small families Plicatulidae and Spondylidae, confined to warm water, are represented by 1 species each. The Ostreidae is represented by at least 1 living species *Lopha frons* (Linné); however, Waller (1973) discovered 1 eroded right valve of a *Neopycnodonte*, and it is possible that this gryphaeid species is also living in Bermuda. The Chamidae has 4 species reported from Bermuda, but the common tropical western Atlantic and West Indian genus *Arcinella* is not present. The large family Mactridae has not been reported from Bermuda, but 3 species of the small family Mesodesmatidae are present. The deep-burrowing Solenidae is not found in Bermuda. The very large family Tellinidae is represented by 14 species in Bermuda, and the closely related families Psammobiidae, Semelidae, and Solecurtidae have 2, 3, and 2 species in Bermuda. However, another family closely related to the Tellinidae, the Donacidae, has not been reported from Bermuda. The small relict families Trapeziidae and Glossidae have 1 species each, and the trapeziid species is a nestler. The 2 most diverse families of marine pelecypods are the Tellinidae and the Veneridae. The Tellinidae is common in Bermuda, but the Veneridae is represented by only 4 species. This imbalance is typical of a sweepstakes route. It is also puzzling that no species of the family Corbulidae has been reported from Bermuda; however the much smaller family Gastrochaenidae has 3 species living in Bermuda. From this brief review of the families and the data furnished in Table 2, it becomes obvious that the shallow-water pelecypod fauna of Bermuda is not well balanced.

Limestone and corals are common in Bermuda, providing suitable habitats for nestlers and rock borers. There appear to be 3 nestling species and at least 7 rock-boring species in the pelecypod fauna of Bermuda.

The pelecypod fauna of Bermuda is well known, but a few additions may be discovered in the future. The sweepstakes route to Bermuda is still open, as Abbott and Jensen (1967) have shown. One apparently recent arrival they reported was *Macrocallista maculata* (Linné). They also include several species of gastropods that apparently are new colonizers of Bermuda. However, these new discoveries and new arrivals are not likely to alter the general composition of the fauna to any appreciable extent.

Abbott and Jensen (1967) also note that some of the species of molluscs of Bermuda attain a larger size than do the same species living in lower latitudes. This phenomenon is probably caused by the lower yearly average temperature of the water at Bermuda as compared to southern Florida or the Bahama Islands. These molluscan species are another example of the cline known as Bergmann's rule, which appears to be quite common in pelecypods and gastropods that secrete calcareous shells.

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THE COMPARATIVE SIZE OF DEPOSIT-FEEDING ANIMALS—

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ABSTRACT: *The largest living species of deposit-feeding animal has a weight of about 5 kg. The truly large animals such as whales, squids, elephants, and man are either suspension feeders, carnivores, herbivores, or omnivores. Extinct species of deposit feeders were probably small to medium-sized animals.*

How do the largest living deposit-feeding animals compare in size with the largest animals having other modes of feeding? As an example of a truly large animal species, we may use *Homo sapiens*. The average weight of an adult person is about 55 kg. I estimated that there are about 700 living species of animals that have a size that equals or is greater than man and that all but about 20 of these are vertebrates (Nicol, 1976). Such animals as man, elephants, lions, alligators, whales, large sharks and fish, and squids, are all omnivores, carnivores, herbivores, or suspension feeders.

Only 12 of the 37 living animal phyla have species that are deposit feeders (Nicol, 1981). Of these 12 phyla, 6 have some terrestrial species, 5 have some fresh-water species, and at least 11 have some marine species. Six of these phyla are found only in a marine environment.

Many deposit-feeding animals are bilaterally symmetrical, soft-bodied, and elongate or shaped like a worm. Because the largest deposit feeders are worm-shaped, they do not have a great weight. Deposit feeders must be mobile to forage for their food, and an elongate, coelomate animal is ideally suited for this habitat. Notable exceptions to these morphological characteristics are seen in the Mollusca, Arthropoda, and Vertebrata. Probably less than 20% of the living species of deposit feeders have well developed calcareous or phosphatic skeletons, which would likely preserve them as fossils.

The deposit-feeding Monoblastozoa, Kinorhyncha, and Nematoda are tiny animals that rarely attain a size of more than 1 mm. Sipunculoids are small to moderately large-sized animals, with a maximum length of about 72 cm, although most are about 10 cm long (Barnes, 1980). The echiuroids have a size range of about that of the sipunculoids. Some of the deposit-feeding annelids are among the larger animals that have this type of feeding, and a few of them attain a length of 3 m. Sipunculoids, echiuroids, and annelids are all worm-shaped or elongate and do not have a great weight, and none probably weighs more than 1 kg. Deposit feeding in the arthropods appears to be confined to some of the aquatic insects and crustaceans (Barnes, 1980). The deposit-feeding arthropods are mostly small animals, less than 10 mm, but a few deposit-feeding crustaceans may attain a length of 14 cm. Deposit-feeding crustaceans are mainly amphipods and a few decapods.

I have noted (Nicol, 1964, 1978) that the deposit-feeding pelecypods, Protobranchia and some tellinaceans, are of small to medium size. These deposit feeders never attain a length of more than 120 mm, and many deposit-feeding species are of 10 mm or less. Deposit-feeding pelecypods are characteristically thin-shelled. Furthermore, deposit-feeding pelecypods have not attained a large size at any time during their geologic history. Besides certain pelecypods, some gastropods (such as *Aporrhais*, *Turritella*, *Viviparus*, and *Struthiolaria*), are deposit feeders, and these gastropods are of small to medium size. Species of *Aporrhais* attain a maximum length of about 60 mm, and a species of *Struthiolaria* attains a maximum length of 85 mm. Some species of *Turritella* are longer than *Aporrhais* and *Struthiolaria*, but they are all slender, having a high spire. Species of *Viviparus* and other deposit-feeding gastropods are smaller than the maximum sizes already mentioned. The largest deposit-feeding pelecypods and gastropods have a weight of no more than 0.5 kg. It is significant that the deposit-feeding molluscs do not attain a large size, and the feeding habits of these animals are comparatively well known. Much larger molluscs are carnivores, herbivores, or suspension feeders, and a few species of molluscs are the largest living invertebrates, as, for example, *Tridacna gigas* (Linné) 250 kg (Rosewater, 1965) and the giant squid at 30,000 kg (MacGinitie and MacGinitie, 1949). See Fig. 1.

Some ophiuroids are deposit feeders, but this class of echinoderms mainly has a small-sized body, and the central disc rarely becomes more than 3 cm, although a maximum size of 12 cm for the central disc has been reported (Barnes, 1980). The largest ophiuroids are generally predaceous and not deposit feeders. Many holothuroids are also deposit feeders, and the maximum size in this class of echinoderms is about 1 m in length with a body

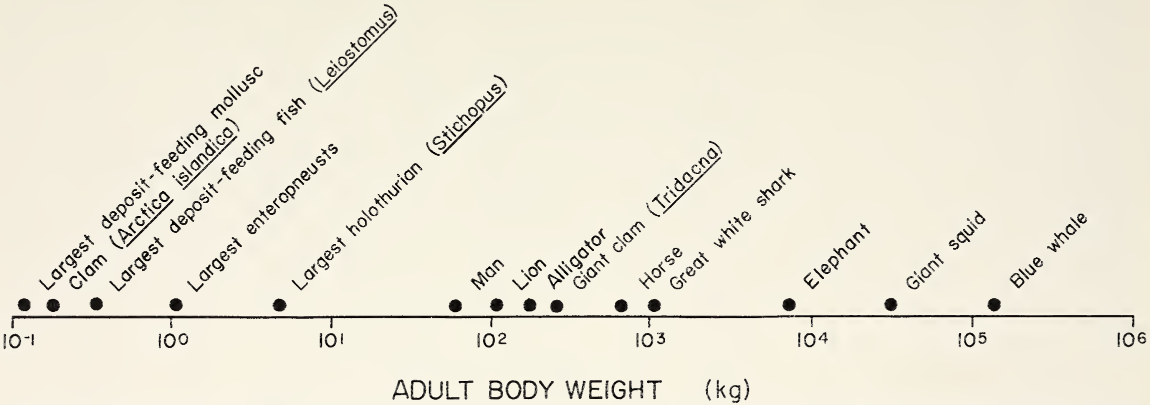

FIG. 1. The adult body weight of the largest deposit-feeding animals as compared to the adult body weight of the largest carnivores, omnivores, herbivores, and suspension feeders, based on a logarithmic scale.

diameter of 24 cm, but most species range from 10 to 30 cm in length. Perhaps the largest living deposit-feeding animals are some species of holothuroids. However, even these large holothuroids are small as compared to man, squids, alligators, and elephants (Fig. 1). The weight of these largest holothuroids probably does not exceed 5 kg.

Many burrowing enteropneusts are deposit feeders, and these animals may attain a length of 1.5 m, although most species are less than half this size. The body of enteropneusts is slender so that a great weight is not attained. The maximum weight of the largest enteropneusts is no more than 2 kg (Fig. 1). A few tunicates are deposit feeders, and these solitary animals may reach a length of no more than 40 cm and some are about half this size.

The relatively few deposit-feeding living vertebrates (about 250 species) rarely reach a length of more than 70 cm, with a maximum weight of no more than 1 kg. Again, it is significant that in a group that is well known (Spector, 1956), the largest species are not deposit feeders.

It appears that deposit feeding and suspension feeding are closely related, and it is difficult in some instances to tell whether a species is a deposit feeder or a suspension feeder. In the Sipunculoidea, Echiuroidea, and Enteropneusta this situation occurs in some species, and these small phyla have only deposit feeders or suspension feeders. In the tellinacean pelecypods some species are deposit feeders whereas other species are suspension feeders, and even within a family of tellinaceans one finds that both types of feeding occur in different species that are otherwise closely related. Much depends on the mode of life as to whether a species of tellinacean will be a deposit feeder or a suspension feeder. If a species is an active burrower, it may be either a deposit feeder or a suspension feeder, but if it is a nestler, it must be a suspension feeder. Deposit feeders must be vagile and benthic. Probably the first deposit-feeding species evolved from a vagile suspension-feeding species. However, it is possible that suspension feeders evolved from deposit feeders later in geologic history.

From this review of deposit-feeding animals, it appears that no species attains nearly the large size or great weight of the largest carnivores, herbivores, omnivores, or suspension feeders. This is likely true of extinct deposit-feeding species of animals as well. Apparently this mode of feeding places a limit to the maximum size that deposit feeders can attain.

Acknowledgments—We are indebted to George H. Burgess and Carter R. Gilbert of the Florida State Museum for providing us with information on deposit-feeding vertebrates.

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Florida Sci. 47(3):197-201. 1984.

POSSIBLE ESTABLISHMENT OF *GEOPHAGUS SURINAMENSIS* (CICHLIDAE) IN FLORIDA[1]

—*Randy J. Metzger and Paul L. Shafland*, Non-Native Fish Research Laboratory, 801 N.W. 40th Street, Boca Raton, Florida 33431

Abstract: *Several specimens of the South American cichlid* Geoghagus surinamensis *were collected from a southeast Florida canal. Our collections and observations document the possible establishment of this exotic fish in Florida.*

Several redstriped eartheaters (*Geophagus surinamensis* Bloch; Fig. 1) were collected recently from a south Florida canal. This species is native to northeastern South America, grows to a maximum of 300 mm TL (Puyo, 1949), and is a popular species in the tropical fish industry (Axelrod et al., 1980).

The first redstriped eartheaters (n = 2) were collected in April 1981 and 5 more were collected in May 1982. From June to July 1982 an additional 34 specimens were collected and several others observed. These fish ranged from 111-214 mm (× =151 mm) total length (TL) and weighed 18-185 g (× =63 g).

The number (n = 41) and sizes (18-185 g) of redstriped eartheaters collected indicate they are reproducing and some recruitment is occurring. Some of these were adults with ripe gonads. Furthermore, a pair guarding a group of about 10 fry was observed and three 15-16 mm TL fry were collected (J. N. Taylor, Florida Atlantic University, Boca Raton, FL, pers. comm). These data document the possible establishment of redstriped eartheaters in Florida. The recentness of this discovery, limited distribution and small estimated population size are, however, insufficient to consider them a permanent (i.e., established) addition to Florida's ichthyofauna.

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[1] Contribution No. 28, Non-Native Fish Research Laboratory, Florida Game and Fresh Water Fish Commission, 801 N.W. 40th Street, Boca Raton, Florida 33431.

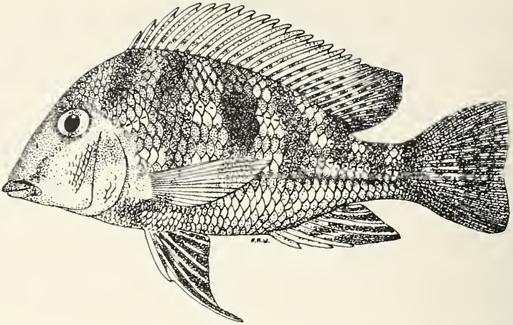

FIG. 1. Adult *Geophagus surinamensis* collected from Snapper Creek during June 1982.

All observations and captures of redstriped eartheaters were in a 1 km stretch of Snapper Creek in Dade County, just north of its intersection with the Tamiami Canal. Snapper Creek is part of an extensive flood control system made up of interconnected, box-cut canals. This system provides a means of rapid range extensions for introduced exotic fishes.

Redstriped eartheaters were observed most commonly on shallow (< 1 m) ledges covered with gravel and sand during a June 1982 collection. Occasionally sand or gravel was picked up, rolled around in their mouths and then expelled. These activities are associated with the redstriped eartheater's feeding habits from which it derives its common name (Loiselle 1980; C. R. Robins, Univ. Miami, Miami Florida, pers. comm.). Other specimens were collected along the vertical canal walls in depths greater than 2 m.

The ornamental fish industry is the likely source of this introduction, via either a home aquarist or one of several tropical fish farms in the vicinity. No other known source of these fish exists in Florida.

The unauthorized release of exotic fishes has occured previously in Florida (Courtenay et al., 1974), and their potential for disrupting aquatic communities has been reviewed by Shafland (1979). Should the redstripped eartheater be a permanent addition to Florida's ichthyofauna, it would be the 17th exotic fish and the 13th cichlid to do so (Shafland et al., 1982).

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Florida Sci. 47(3):201-203. 1984.

ADDITIONS TO THE LATE PLEISTOCENE AVIFAUNA OF BRADENTON, MANATEE COUNTY, FLORIDA—*Jonathan J. Becker*, Department of Zoology, University of Florida, Gainesville, Florida 32611

Abstract: *Three avian species, previously unknown from the late Pleistocene Bradenton local fauna, are reported*–Ciconia maltha, *an extinct species of stork;* Lophodytes cucullatus, *the hooded merganser; and* Melanerpes *cf.* M. carolinus, *the red-bellied woodpecker. This brings the number of avian species known from this locality to 13, including 2 extinct species.*

The Bradenton local fauna is a vertebrate fossil assemblage, originating from dark sands, from 2 main sites within the city limits of Bradenton (Bradenton Field—NE¼, NW¼, Section 2, Range 17 E., Township 35 S.; and Bradenton 51st Street—Section 34, Range 17 E., Township 34 S.), Manatee County, Florida. Most vertebrates are fresh water forms. Beach sands stained with tannic acid are present which indicate a pond or stream close to the beach (Auffenburg, 1963). The presence of *Terrapene carolina putnami* also indicates a lowland, near-shore area (Auffenburg, 1958). Mammals known from this local fauna indicate a Rancholabrean age, most likely from the Sangamonian interglacial, based on the presence of *Bison latifrons* and *Microtus hibbardi* (Webb; 1974, Kurtén and Anderson, 1980).

Wetmore (1931), in his review of Florida's Pleistocene avifauna, described the following 8 species of birds in the American Museum of Natural History collections from Bradenton: *Ardea herodias*, great blue heron; *Egretta thula*, snowy egret; *Nycticorax nycticorax*, black-crowned night-heron; *Anas fulvigula*, mottled duck; *Teratornis merriami*, teratorn; *Meleagris gallapavo*, wild turkey; *Grus canadensis*, sandhill crane; and *Fulica americana*, american coot. Wetmore later (1945) added *Phalacrocorax auritus*, double-crested cormorant, and Brodkorb (1963:230) reported *Podilymbus podiceps*, pied-billed grebe, from this local fauna.

I report on all avian fossils from Bradenton in the Vertebrate Paleontology collections of the Florida State Museum and add 3 new taxa of birds to this local fauna, bringing the total number of species to 13.

Podilymbus podiceps (Linnaeus). pied-billed grebe. UF 2471. Complete left humerus.

Ciconia maltha L. Miller. extinct stork. UF 2963. Complete left tarsometatarsus. Compares well with UF 15708, distal tarsometatarsus, from the late Pleistocene deposits of the Ichetucknee River in size and all characters.

Lophodytes cucullatus (Linnaeus). hooded merganser. UF 3466. Complete left humerus. Agrees well with the modern hooded merganser in size, presence of an open pneumatic fossa, large angular deltoid crest (abraded in fossil), and a humeral shaft which appears sigmoidal in anconal (caudal) view.

cf. *Teratornis merriami* L. Miller. extinct teratorn. UF 2664. Distal left ulna. Ulna referred to *T. merriami* on the basis of size. Greatest distal diameter of the ulna 25.5 mm in the above specimen; 25 mm reported by Miller (1925).

Melanerpes cf. *M. carolinus* (Linnaeus). red-bellied woodpecker. UF 6603. Distal left humerus, slightly abraded; UF 6604. Complete right tarsometatarsus. Humerus close to both *M. carolinus* and *M. erythrocephalus* in size, but is too abraded for a positive identification. Tarsometatarsus most similar to *M. carolinus* in overall length and proportions. However, the tarsometatarsi of both the red-headed and the red-bellied woodpeckers appear very close osteologically and one would need a series of fossil specimens to positively identify the species.

The above avian species add support to the ecological interpretation of this local fauna as a freshwater stream or pond near a wooded area.

ACKNOWLEDGMENTS—I thank Pierce Brodkorb, S. David Webb, and Gary S. Morgan for their comments which improved this manuscript. I also thank Pierce Brodkorb for the loan of recent skeletons for comparisons and S. David Webb and Bruce J. MacFadden, Florida State Museum, for allowing me to study specimens in their care.

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Florida Sci. 47(3):203-204. 1984.

INTESTINAL HELMINTHS OF THE CUBAN ANOLE, *ANOLIS SAGREI SAGREI*, FROM TAMPA, FLORIDA

—(1) *W. Wayne Price and (2) Harold Underwood*, (1) Department of Biology, University of Tampa, Tampa, Florida 33606 and (2) Department of Biology, Texas A&M University, College Station, Texas 77843.

ABSTRACT: *Three species of intestional helminths were recovered from 100 Cuban anoles,* Anolis sagrei sagrei, *collected from residential areas of Tampa, Florida between May and October, 1981.* Physaloptera squamatae *was in the stomachs of 56(56%) hosts with a mean intensity of infection of 19.1 worms.* Cyrtosomum scelopori *was recovered from the intestine less frequently (35%), but had a higher mean intensity (99.6).* Mesocoelium monas *was in the intestine and stomach of 10% of the hosts and exhibited the lowest mean intensity of infection (3.6).* Physaloptera squamatae *and* M. monas *are new host records. Significant positive correlations were observed between the prevalence and mean intensity of the 2 nematodes and host length. Male and female Cuban anoles had similar prevalences and mean intensities for all parasites.*

THE Cuban anole, *Anolis sagrei sagrei*, was probably introduced to southern Florida from Cuba and has established populations in the Florida Keys, southern Florida, and the Tampa–St. Petersburg area (Ruibal, 1964; Conant, 1975). The only study of the helminth fauna of this host was done by Otero (1970) in Cuba. He examined 21 lizards and reported 2 species of digenetic trematodes, *Urotrema scabridum* Braun, 1900 and *U. wardi* Perez Vigueras, 1940, and 2 species of nematodes, *Cyrtosomum scelopori* Gedoelst, 1919 and *Skrjabinoptera phyrynosoma* (Ortlepp, 1922). We investigated the endohelminths of *A. s. sagrei* in Tampa, Florida, where the lizard is abundant.

METHODS—One hundred Cuban anoles were collected from residential areas of Tampa, Florida from May–October, 1981. Lizards were taken to the laboratory alive, measured (snout-vent length to nearest 0.5mm), sexed, and necropsied within 24 hr. The stomach and intestine were examined separately. The intestine was divided into 3 equal segments which were designated 1, 2, and 3, respectively, starting at the anterior end. Statistical analysis of data included: correlation and chi-square analyses and Student's t-test. Values were considered statistically significant at $P<0.05$. Representative helminths recovered were deposited in the University of Tampa Invertebrate Collection.

RESULTS AND DISCUSSION—Sixty (60%) Cuban anoles were infected with at least 1 of the 3 endohelminths recovered. The prevalence, mean intensities, and intensity ranges for the 2 nematodes and 1 digenetic trematode are in Table 1. *Physaloptera squamatae* Harwood, 1932 (Nematoda:Spirurida) was the most common parasite in 56% of the hosts. *Cyrtosomum scelopori* Gedoelst, 1919 (Nematoda: Oxyurida) was observed less frequently (36%), but had a much greater mean intensity and wider range of numbers per host. Both the prevalence and mean intensity of *Mesocoelium monas* Rudolphi, 1819 (Trematoda: Brachycoeliidae) were low. The former nematode and *M. monas* are new host records.

Physaloptera squamatae was found only in the stomach of *Anolis s. sagrei. Cyrtosomum scelopori* occurred only in the intestine with segment 3 containing most of the worms. The mean intensity for segment 3 (95.9) was significantly different from segments 2 (15.0) and 1 (1.6) (Student's t-test,

Table 1. Prevalence, mean intensities, and ranges of intensities from parasites in *Anolis s. sagrei* of various length classes (mm) from Tampa, Florida.

			Physaloptera squamatae			*Cyrtosomum scelopori*			*Mesocoelium monas*		
Host Length Class	Mean Host Length	No. Exam.	No. Inf. (%)	Mean Intensity ± SD	Range	No. Inf. (%)	Mean Intensity ± SD	Range	No. Inf. (%)	Mean Intensity ± SD	Range
15-19.9	18.7	10	0(0)	—	—	0(0)	—	—	0(0)	—	—
20-24.9	21.7	17	3(18)	2.0 ± 1.7	0-4	0(0)	—	—	0(0)	—	—
25-29.9	27.1	10	3(30)	2.3 ± 1.5	0-4	2(20)	1.0	0-1	0(0)	—	—
30-34.9	31.4	10	6(60)	5.2 ± 4.8	0-13	0(0)	—	—	0(0)	—	—
35-39.9	36.6	10	5(50)	5.4 ± 4.0	0-9	3(30)	6.5 ± 7.8	0-12	3(30)	5.0 ± 5.3	0-11
40-44.9	42.2	10	6(60)	7.3 ± 6.1	0-16	4(40)	83.5 ± 92.9	0-218	2(20)	3.0 ± 2.8	0-5
45-49.9	46.1	11	11(100)	34.2 ± 37.6	1-132	10(91)	101.1 ± 46.5	0-144	2(18)	1.5 ± 0.7	0-2
50-54.9	51.4	10	10(100)	13.6 ± 11.9	3-44	5(50)	93.8 ± 48.7	0-172	1(10)	1.0	0-1
55-59.9	56.4	10	10(100)	36.7 ± 57.4	2-185	10(100)	142.5 ± 106.9	7-325	2(20)	5.5 ± 5.0	0-9
60 +	62.5	2	2(100)	37.0 ± 48.1	3-71	2(100)	117.0 ± 66.5	70-164	0(0)	—	—
TOTALS		100	56(56)	19.1 ± 32.7	0-185	36(36)	99.6 ± 80.3	0-325	10(10)	3.6 ± 3.6	0-11

$P<0.001$). Mean intensities in the first 2 segments were not significantly different. Of the 36 *M. monas* recovered, 5 were from the stomach, 30 from segment 1 and 1 from segment 3 of the intestine.

A significant positive correlation existed between prevalence ($r=0.95$, $P<0.005$) and mean intensity ($r=0.86$, $P<0.005$) of *P. squamatae* and the mean host length of each host length class (Table 1). All Cuban anoles of 45 mm or greater were infected with this nematode. A similar significant positive relationship concerning prevalence ($r=0.91$, $P<0.005$) and mean intensity ($r=0.92$, $P<0.005$) and host length existed for *C. scelopori*. However, few infections were found in anoles <35 mm in length. This increase in infection parameters of the 2 nematode species with increasing lizard length may be attributed to an increase in feeding level and length of the alimentary canal with increased body size. As the alimentary canal gets larger, it provides more space and a larger surface area for parasite attachment. The feeding habits may also change with increasing length, thus altering prevalence and mean intensity in larger hosts.

There was no significant correlation between prevalence ($r=0.36$) and mean intensity ($r=0.39$) of *M. monas* and host length. Infections were confined to anoles between 30-60 mm and both parameters were low in all size classes. This low infection level could be due to a scarcity of the proper intermediate hosts in the diet of anoles. A cursory inspection of stomach contents of the anoles yielded no gastropods which serve as second intermediate hosts for those brachycoeliid trematodes with known life cycles (Yamaguti, 1975).

There were no significant differences (chi-square test) between the number of male and female hosts infected with each species of endohelminth. Also, the mean intensities of each parasite species in male and female lizards did not differ significantly (Student's t-test). This could indicate that both sexes of the Cuban anole have similar feeding habits and are equally susceptible to infection.

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Florida Sci. 47(3):205-207. 1984.

REVIEW

Robert J. Laws. *Solar Cells*. Pp. 1-127. Enslow Publishers.

THIS BOOK can be read easily in one session. It is well laid out with diagrams and examples easy to follow. I am not aware of any book available which covers similar material. It is, as the author claims, a guide for the do-it-yourselfer with obvious advocacy by the author that readers should start their own photovoltaic systems, a condition which would, of course, enhance book sales! Economics of construction are considered, as well as how to set up a system.

I found no technical faults although in a book written for the layman, it is easy to find small quibbles, e.g., on page 11 introducing the solar cell, the sun's energy does not "create an electric current" unless there is a complete circuit. Photovoltaics refers to generation of a voltage. And on page 83, in the Appendix, one wonders if there were risk of applying outside the field of solar cells the statement that "in series the voltage output doubles and the current remains the same." Two 6 volt automobile batteries in series would not generate the same current as one 6 volt battery! But these misinterpretations of the intended meaning of the author are of a very minor character. Overall, I found the book quite instructive, free of technical jargon, clear and not confusing in any of the sections where design and calculations enter. It does not seem to be material which will become "dated" quickly (although the list of suppliers may well change with time).

I am not in a position to judge whether the author's optimism about future costs and universal need for solar cells is justified. But the technical content appears sound. It does not, of course, cover any details on solar cell fabrication, which is quite outside the author's interest.—*Jack H. Noon*, Department of Physics, University of Central Florida, Orlando, Florida 32816.

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Submit a typewritten original and one copy of the text, illustrations, and tables. All typewritten material—including the abstract, literature citations, footnotes, tables, and figure legends—shall be double-spaced. Use one side of 8½ × 11 inch (21½ cm *X* 28 cm) good quality bond paper for the original; the copy may be xeroxed. Margins should be at least 3 cm all around. Number the pages through the Literature Cited section. Avoid footnotes and do not use mimeo, slick, erasable, or ruled paper. Use metric units for all measurements. Assistance with production costs will be negotiated directly with authors of papers which exceed 10 printed pages of text. *Excess over 10 pages by an author in a single volume will result in charges for additional pages.*

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ABSTRACT—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

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Biological Sciences

VEGETATION OF THE ARCHBOLD BIOLOGICAL STATION, FLORIDA: AN EXAMPLE OF THE SOUTHERN LAKE WALES RIDGE

(1)WARREN G. ABRAHAMSON, (1)ANN F. JOHNSON,
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ABSTRACT: *The vegetation of the Archbold Biological Station (ABS, 1590 ha), one of the largest and most representative examples of the natural landscape of the southern end of the Florida Lake Wales Ridge, is described. The major associations include: southern ridge sandhills, sand pine scrub, scrubby flatwoods, flatwoods, swale, bayhead, and seasonal ponds. Sandhills, scrub, and scrubby flatwoods occur on more elevated and well-drained sands, while the remaining types occupy less elevated and more poorly drained soils. Plant species diversity (H') was highest for sandhills and scrubby flatwoods, lowest for scrub (rosemary phase) and swale. Horn's index of community similarity (R_0) showed 2 clusters of associations: (1) the well-drained scrub, scrubby flatwoods, and southern ridge sandhills and (2) the poorly drained flatwoods, swales, and bayheads. This analysis also indicated that bayhead, swale, and rosemary scrub were the least similar to other ridge associations. Ridge associations are influenced by fire and each association differs in flammability, modal fire frequency, and resiliency. Evidence indicates that long-term successional changes in the associations studied are extremely slow, with the associations of well-drained sites being especially stable. Stability of microclimate in 5 of the major associations ranked: bayhead > mature scrub > flatwoods > sandhills > scrubby flatwoods. Historical natural (e.g., hurricanes, fires) and anthropogenic (e.g., turpentining, logging, grazing) influences on the vegetation associations of the study area have resulted in little change in species composition, indicating that ridge associations are relatively stable. The vegetation types at ABS were compared to similar associations in other parts of Florida, noting geographical extents and the unique features of southern Lake Wales Ridge associations. At ABS, 43 out of a total of 470 species (9 % of the flora) are endemic to Florida. Nine of the 43 endemics are confined to the Lake Wales Ridge, with 3 additional ridge endemics near or adjacent to, but not on, the study area proper.*

THIS PAPER presents an analysis of the vegetation of the Florida southern Lake Wales Ridge region as represented on the Archbold Biological Station (ABS) in Highlands County, 12 km south of the town of Lake Placid (27°11'N lat., 81°21'W long., Fig. 1). The 1580 ha main station property is one of the largest and most representative tracts of the natural southern ridge vegetation remaining. Its east-west axis transects the major portion of the ridge and its north-south axis extends from the ridge south to the transition zone to coastal terrace, thus encompassing most of the geologic and topographic features associated with the ridge. All of the major vegetation types of the southern ridge area are present on the ABS with their natural ecotones intact.

The southern end of the Lake Wales Ridge in south-central peninsular Florida is a major biogeographic region of the state, because of the occurrence of a comparatively large number of endemic species and subspecies of plants and animals. (Neill, 1957). The majority of the characteristic species of the southern ridge section is restricted to sand pine scrub and other xeric vegetation types which, during the Wisconsin glaciation, may have been even more widespread in the region than today (Watts, 1980). With the exception of the Ocala Scrub in Marion County, the most extensive development of this near-exclusive Floridian vegetation type is found on the Lake Wales Ridge in Highlands County.

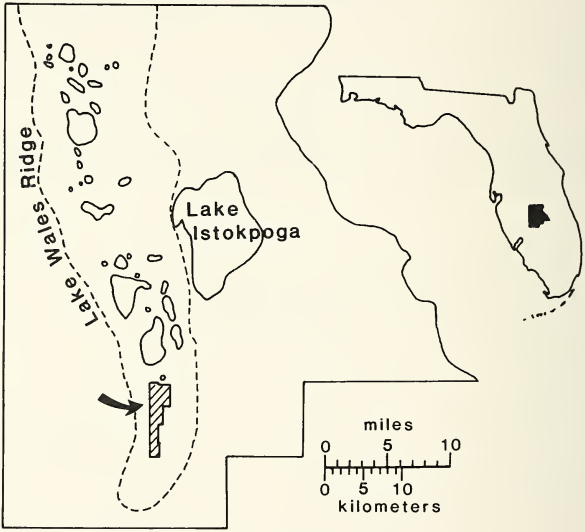

FIG. 1. Archbold Biological Station study area.

Despite the biological significance of the southern ridge region, its vegetation has not previously been analyzed or described in detail. Early accounts of the vegetation of the area were given by Harper (1921, 1927) and Davis (1943). Laessle (1958, 1967) included descriptions of sand pine scrub and "Caribbean" pine - turkey oak associations of the southern ridge section in his study of the Florida scrub. Davis' (1967) general vegetation map of Florida delineated 2 major vegetative types on the southern ridge: scrub and sandhill. Of the detailed reports on Florida plant communities (Harper, 1914, 1921, 1927; Henderson, 1939; Carr, 1940; Kurz, 1942; Laessle, 1942; Davis, 1943; Hubbell et al., 1956; Harlow, 1959; Monk, 1965, 1968; and

Richardson, 1977) our classification most closely follows that of Laessle (1942).

Description of Study Site—*Physiography and Geology:* Based on Brooks' (1981a) physiographic map of Florida, ABS lies in 2 of the major physiographic regions of the state: the Central Lakes and Southwestern Flatwoods districts. Most of ABS is included within the Eastern Complex of the Central Ridge division of the Lake Wales Ridge subdistrict of the Central Lakes district, while the extreme southern portion is mapped as Carlton Ranch Ridge subdistrict of the Southwestern Flatwoods district.

The Lake Wales Ridge, characterized by residual sandhills, relic beach ridges, and paleo dunes, is the topographic crest of the central and south-central peninsular region (Brooks, 1981a). It, together with other high ridges in central Florida, has been interpreted as a remnant of a formerly more extensive upland preserved as the result of some linear coastal feature present during higher stands of sea level (White, 1970). MacNeil (1950) and White (1958) considered the Lake Wales Ridge to be the severed distal segment of a longer ridge whose northern segment is represented by the present Trail Ridge in northeastern Florida and southeastern Georgia. The edge of the ridge lies at about the 30 m contour, which marks the approximate level of the Wicomico Sea in early Pleistocene (Brooks, 1968, 1973). The higher portions of the ridge show evidence of the earlier Okefenokee shoreline. A valley averaging about 3 km in width and containing numerous solution lakes occupies the central axis of the southern part of the ridge (White, 1970). ABS includes the eastern crest of the Lake Wales Ridge, the southernmost portion of the intraridge valley, and a narrow section of the western side of the ridge.

The Lake Wales Ridge is underlaid by the Miocene Hawthorn formation comprised of marine sands, clays, marls, and sandy limestones (Puri and Vernon, 1964). The Hawthorn formation is generally covered by a mantle of paleo beach and dune sand of varying thickness. ABS is located in one of the major paleo dune systems of the central ridge region (White, 1958). A geologic cross section extending east to west through Lake Annie about 0.5 km north of the northern boundary of the study area (Bishop, 1956) shows the Hawthorn formation extending to the underlying limestone at a depth of about 137 m, with the overlying mantle of sand being thinnest in the intraridge valley and thickest on the adjoining higher portions of the ridge. According to Brooks (1981b), the Hawthorn formation (Interlachen facies) is exposed on the highest portion (Red Hill) of the study area on the eastern crest of the Lake Wales Ridge. It is deeply weathered, with a thick residual paleo soil. The remainder of the ABS is covered by deeply weathered, coarse to fine beach and dune sands of Plio-Pleistocene age and undifferentiated sands of Pliocene origin.

Topography: Elevations in the study area range from appoximately 36-67 m (U.S.G.S. Childs, Florida, 7.5′ quadrangle). The highest point, Red Hill, marks the crest of the Lake Wales Ridge flanking the eastern side of the intraridge valley. The top of the hill forms a fairly level plateau with an elevation of 61 m. The slopes are steeper on the west and northwest sides of the hill than on the eastern side, elevations along the northwest side increasing about 6 m per 100 m horizontal distance.

The intraridge valley forms a shallow trough with elevations generally below 44 m. The floor of the valley slopes gradually downward to the north and consists of a complex mosaic of depressions, ridges, and knolls. Elevations range from about 40-46 m in the southern part of the ABS to about 36-40 m at the northwest corner. The topography of the valley floor presumably reflects its history as a shallow sea bottom during the high stand of the Okefenokee Sea; the ridges and knolls represent former bars or islands. Some of the depressions in the former sea bottom may have been secondarily deepened by karst activity following the fall in sea level. This is certainly the origin of a small (30 m dia.), circular pond located in a depression in the southern part of ABS along the same axis as the large sinkhole lakes of the Lake Wales Ridge, which begin 6 km to the north.

A distinctive topographic feature of the valley section is 3 north-south oriented, linear series of ridges and knolls. These chains are subparallel and evenly spaced across the valley, suggesting an origin as sand bars paralleling the former shore line. In addition to these chains, there are many other knolls and ridges of varying size scattered throughout the valley with no obvious orientation. These tend to be higher (>46 m) and more numerous in the southern end of the property.

The irregular western wall of the intraridge valley (46 m contour) extends a short distance into the western side of the property for a north-south distance of about 4 km. Its maximum elevation in the study area is about 49 m.

Soils: A detailed soil survey performed in 1982 and mapped at a scale of 1 cm = 48 m (1:4800) by L. Carter and D. Lewis, U.S.D.A. Soil Conservation Service, identified 23 soil types on the study area. These are all deep sandy soils derived from thick beds of marine, aeolian, or fluvial deposits. They have low clay and silt content, generally rapid permeability, low available water capacity, and are usually acidic (pH range 3.6-8.4). Entisols (Archbold, Astatula, Basinger, Lake, Orsino, Paola, Pompano, Satellite, St. Lucie, Tavares) comprise 77% of the total; Inceptisols (Placid, Sellers), 2%; and Spodosols (Duette, Cassia, Immokalee, Myakka, Daytona, Zolfo), 21%. Sanibel and Sellers are the only types having a well developed muck layer overlying the mineral soil. The soils range from excessively well-drained, with highest water tables varying from 1.8 m to more than 3 m, to very poorly drained with maximum water tables varying from 0.6 to less than 0.25 m. The drainage characteristics and areas of the soil types represented on the study area are in Table 1. The most abundant types, individually accounting for 10% or more and with a cumulative total of 49%, include Satellite, Pompano, and Astatula—in order of extent. Paola, Duette, Pompano depressional, and Immokalee are also relatively well-represented

TABLE 1. Areas of soil types of Archbold Biological Station.

Drainage Class and Soil Series	Area	
	Hectares	Percent of Total
Excessively well-drained	303	19.7
Astatula	157	10.2
Paola	126	8.2
St. Lucie	13	0.9
Lake	7	0.5
Moderately well-drained	304	19.7
Duette	133	8.6
Archbold	57	3.7
Daytona	56	3.6
Orsino	48	3.1
Tavares	10	0.6
Somewhat poorly-drained	353	22.9
Satellite	316	20.6
Zolfo	33	2.2
Cassia	3	0.2
Poorly Drained	546	35.5
Pompano	282	18.3
Pompano depressional	119	7.7
Immokalee	64	4.2
Basinger	43	2.8
Immokalee depressional	15	1.0
Myakka	14	0.9
Myakka depressional	4	0.3
Basinger depressional	4	0.3
Very poorly drained	33	2.1
Placid	22	1.4
Sanibel	5	0.3
Sellers	5	0.3

(4.2-8.6%). Taken together with the previous types, these 6 comprise 79% of the soils of ABS. The most well-drained soils are largely restricted to the hill, where they exhibit distinct zonation: Lake on the top, Astatula on the upper slopes, and Paola below. The zone of Paola soil corresponds to the approximate shoreline of the Okefenokee Sea (46 m). The soils of the intraridge valley are more diverse, generally cover smaller areas, and form a complex mosaic of better drained types on ridges and knolls and more poorly drained types on lower sites.

Climate: The climate of the southern ridge region is characterized by hot, wet summers and mild, dry winters. The annual mean daily temperature at ABS, based on the 29-yr period 1952-1980, is 22.3°C, with the highest monthly mean (27.5°C) occurring in August and the lowest

(16.0°C) in January. Extreme temperatures recorded during the 29-yr period were 39.4°C in May 1953 and -8.3°C in December 1968. Mean maximum and minimum summer (June-August) temperatures range from 33.4-34.1 and 19.6-21.4°C, respectively. Corresponding values in winter (December-February) were 23.8-24.3 and 8.7-9.5°C. Lowest winter temperatures are usually above freezing, although one to several cold spells, with temperatures falling below freezing at night, usually occur each year. Cold spells generally do not last for more than several days. From 1952 to 1980, minimum daily temperatures below freezing were recorded in all months from November through March. Below freezing temperatures occurred in January in 26 out of 29 yr.

The 29-yr record shows no obvious long-term trends or cycles of colder winters. Winters with below average temperatures occur at 1 to 6-yr intervals, with 9 of 12 "colder than normal" winters occurring in succession for 2 (3 cases) or 3 (1 case) years.

The shape of the 24-hr air temperature curve is generally similar throughout the year, with minimum temperatures occurring about 0500-0600 and maximums about 1400-1500. The rise in temperature during the morning is faster than the decrease in late afternoon-evening.

Annual mean daily soil temperatures at the ABS main weather station for the 5-yr period 1975-1981 were: 24.6°C at 2.5 cm depth, 26.2°C at 5 cm, and 25.8°C at 15 cm. The lowest mean daily soil temperature at all depths occurred in January and the highest in August. Mean daily maximum and minimum temperatures at each depth in January were: 2.5 cm. - 22.7/13.9 ; 5 cm - 22.5/14.2 ; 15 cm - 21.1/16.3 . Corresponding values in August were: 2.5 cm - 36.5/25.4 ; 5 cm - 36.2/26.0 ; 15 cm - 33.0/28.0. These values clearly show the narrower range of soil temperatures in winter compared with summer and the increased stability of soil temperature with depth, particularly at 15 cm, at both seasonal extremes. The smallest range of daily soil temperatures (difference between maximum and minimum at any given depth) was 8°C in December, and the highest was 14.6°C in April. The seasonal difference reflects the divergence of the daily temperature curves at 2.5 and 5 cm from that at 15 cm in spring as the result of faster warming at the shallower depths and the convergence of the curves in fall due to faster cooling at 2.5 and 5 cm than at 15 cm.

Mean annual rainfall recorded at ABS over a 49-yr period (1932-1980) was 1374 mm, with extremes of 1947 and 908 mm. The rainy season normally extends from June through September, with an average of 61% of the annual precipitation falling during this 4-mo period. The months with highest and lowest mean precipitation are July (221 mm) and December (41 mm), respectively. The highest rainfall recorded in any month was 555 mm in September 1948. The month with most variable rainfall (coefficient of variation, C.V. = 98%) is January, whereas precipitation in August is least variable (C.V. = 40%). The 49-yr rainfall record indicates a period of 14 yr from 1932 to 1946 with annual rainfall fluctuating closely around the long-term average, with the mean for the period (1357 mm) being only about 1% below the 49-yr mean. From 1947 to 1960, annual rainfall averaged 1487 mm or about 8% above the long-term mean. Average annual rainfall (1307 mm) over the remaining 20-yr period, 1961-1980, was 5% below normal.

Relative humidity (RH) ranges from a day-time low of approximately 30% to a night-time high of about 80%, with relatively little seasonal change. Day-time RH shows the greatest seasonal variation, ranging from a mean at 1300 hr of approximately 30% in April to 40% in January. The daily RH curve is the inverse of temperature, with maximum RH on days without rain occurring between 2400 and 0600 hr and minimums from 1300 to 1500 hr.

METHODS—Soil analyses (pH, organic matter, and nutrients) for all sites, except pH for the seasonal ponds, were performed by the Soil Testing Laboratory of the University of Florida, Gainesville. Samples were composed of subsamples systematically collected at permanent study sites. Samples were air-dried before analysis.

The pH of the seasonal pond soils was measured by shaking 30g of dried soil with 60 ml of distilled water for 5 min, filtering, and measuring the pH of the filtrate.

Soil moisture data were obtained by sampling the upper 0-25 cm of soil. Between 100 and 200g of soil were weighed in their closed collecting containers, the containers opened and the soil samples dried to constant weight, then the containers closed and reweighed. The percentage of moisture in each sample was calculated by dividing the amount of moisture by the dry-weight of the soil (excluding containers) in each sample. Eighty samples were taken from 5 associations in August 1970 and January and April 1971, and an additional 198 samples were collected from 22 permanent sampling stations between 9 September 1980 and 18 January 1981.

Maximum and minimum air and soil temperatures were recorded weekly at a representative site in southern ridge sandhill, sand pine scrub, scrubby flatwoods, flatwoods, and bayhead associations unburned for over 50 yr. Air temperature thermometers were located approximately 30 cm above ground in a standard instrument shelter; soil temperature probes were positioned at a depth of 5 cm.

Once vegetation categories had been decided upon from general reconnaissance, vegetation was mapped onto aerial photographs at a scale of 1 cm = 48 m (1:4800). ABS was carefully traversed to field check the aerial photograph interpretations and to delineate the subcategories (=phases) of the major vegetation associations.

Quantitative data on the composition of particular stands were obtained by 1 of 3 methods: 1) modified line intercept (Strong, 1966), 2) nested quadrats (Weaver and Clements, 1938; Oosting, 1956), or 3) belt transect (Brower and Zar, 1977). The modified line intercept method was used for all sampling of southern ridge sandhill (hickory phase), sand pine scrub (rosemary phase), scrubby flatwoods (inopina oak phase), flatwoods (wiregrass phase), flatwoods (gallberry phase), and swale. Two hundred meters of vegetation were sampled at each site. Nested quadrats were used for each major vegetation association in the hill area and adjacent eastern edge of the intraridge valley. Ground cover (<30 cm in height) was sampled by 1 x 1m quadrats, shrub layer (30 up to 300 cm in height) by 2 x 2m quadrats, and tree layer (>300 cm in height) by 10 x 10 m quadrats. Eighteen nested quadrats were sampled for southern ridge sandhill (turkey oak phase), sand pine scrub (oak understory phase), and scrubby flatwoods (52-yr unburned inopina oak phase); 13 quadrats for palmetto flatwoods and 5 quadrats for bayhead. Data recorded included litter cover and depth; height and maximum crown width for herbs; height, maximum crown width, and stem diameter at a height of 15 cm for shrubs; and height, maximum crown diameter, and diameter at breast height for trees. Dead trees were also tallied. Twenty seasonal ponds were sampled using a 1 m-wide belt transect from the center to the margin (saw palmetto border) of the pond. Soil pits were dug to the water table in each vegetation zone along the transects. Percentage cover of each species was estimated in every square meter along the transect and the elevation change (cm) across each meter was also measured using a beach profiler (Hoyt, 1971) and a Suunto clinometer. The latter was also used to measure the elevation of 5 rosemary stands above the maidencane (*Panicum hemitomon*) zone of adjacent seasonal ponds.

Measuring plant species diversity in associations composed primarily of sprouters and vegetatively propagating plants poses sampling problems as a result of the patchiness of the "individuals" and the difficulty of defining the genetic individual (Abrahamson, 1980; Poole, 1974). To minimize these difficulties, percentage cover data were used with the Shannon-Weaver and evenness (expressed as how close the set of observed species abundances were to the maximum possible diversity for that set) indices (Brower and Zar, 1977).

Horn's (1966) index, R_0, of community similarity was used to indicate how similar or dissimilar the various associations were from one another. The utility of the Horn's index stems from its being based on both species presence and relative abundances (in this case percentage cover). The index ranges from 1 if all species are common to both associations and their abundances are equal, to 0 if no species are common to both samples.

Nomenclature in this study follows the list of vascular plants of the Archbold Biological Station (Vander Kloet, 1979), which relies partially on Long and Lakela (1971) and Radford, Ahles, and Bell (1964). Workers in this region should also consult Wunderlin (1982).

Aerial photographs covering the period from 1940 to 1981; timber surveys conducted by Stenberg in 1982 (ABS files) and Little in 1921 and 1922 (ABS files); land survey notes and plats by Childs in 1870, Jackson in 1859, and Kimmell in 1917; and a history of fires on the study area compiled by Abrahamson (1981) from records of J. N. Layne and C. E. Winegarner and other sources provided information on past conditions in and around the study site. Field notes of J. N. Layne and C. E. Winegarner were a further source of background information on the area from 1967 to the present. Abrahamson's (1984a, 1984b) prescribed burning studies at ABS supplied data on community and species response to fire.

RESULTS AND DISCUSSION—*Description of Vegetation Associations:* Most of the study area is little modified by human disturbance. Approximately 5.5 ha (0.4%) of the 1580 ha is landscaped. Another 2.9 ha (0.2%) of the study area was previously disturbed and is now in old field condition. Approximately 1.4 ha (0.1%) consists of groves of fruit or ornamental trees. Thus, approximately 99.4% or 1570 ha of the study site is natural vegetation (Table 2).

The distribution of the vegetation associations on the study area is in Fig. 2. This map shows only the major associations and does not include the various subdivisions (phases) described below. A detailed vegetation map is available upon request from the Archbold Biological Station. Figure 3 presents 3 somewhat diagrammatic East-West transects through the study area showing the relationships among soil types, vegetation associations, and topography.

Southern Ridge Sandhills: The southern ridge sandhill community, previously referred to as "Caribbean" pine-turkey oak by Laessle (1967) and slash pine-turkey oak by Douglass and Layne (1978), is 3-layered with tree, shrub, and ground cover layers. The tree layer is comprised of south Florida slash pine (*Pinus elliottii* var. *densa*), turkey oak (*Quercus laevis*), and scrub hickory (*Carya floridana*), with a rare longleaf pine (*Pinus palustris*). The pine canopy is typically 8-10 m in height, while the deciduous tree canopy is generally lower at 3-4 m. The mature turkey oaks in the southern ridge sandhills tend to be smaller than in typical north Florida sandhills. Relative abundance of turkey oak and scrub hickory provides a basis for recognition of 2 phases of sandhills: turkey oak phase in which both species are conspicuous, and scrub hickory phase with frequent scrub hickory but little or no turkey oak present. The scrub hickory phase typically has a denser understory than does the turkey oak phase.

TABLE 2. The area and percentage of total area of the vegetation associations and their phases of the Archbold Biological Station.

Association	Area (ha)	% Total Area
Southern Ridge Sandhill—turkey oak	89.71	5.64%
Southern Ridge Sandhill—hickory	137.01	8.62%
Sand Pine Scrub—rosemary	36.34	2.29%
Sand Pine Scrub—oak understory	142.93	8.99%
Scrubby Flatwoods—inopina	477.63	30.05%
Scrubby Flatwoods—live oak	102.69	6.46%
Scrubby Flatwoods—bahia grass	6.83	0.43%
Flatwoods—wiregrass	145.66	9.16%
Flatwoods—cutthroat grass	7.63	0.48%
Flatwoods—gallberry	84.87	5.34%
Flatwoods—palmetto	156.31	9.83%
Flatwoods—fern understory	3.04	0.19%
Swale	14.34	0.90%
Bayhead	5.52	0.35%
Seasonal Ponds	169.41	10.66%
Permanent Water Pond	0.04	0.003%
Man-Modified-landscaped	5.51	0.35%
Man-Modified-old fields	2.86	0.18%
Man-Modified-grove	1.38	0.09%
TOTALS	1589.71	100.01%

Species in the shrub layer that are capable of reaching canopy height include myrtle oak (*Quercus myrtifolia*), sand live oak (*Q. geminata*), Chapman's oak (*Q. chapmanii*), and rusty lyonia (*Lyonia ferruginea*). In long unburned stands, sand pine (*Pinus clausa*) also frequently occurs in the canopy layer. Additional shrub species include scrub palmetto (*Sabal etonia*), saw palmetto (*Serenoa repens*), palafoxia (*Palafoxia feayi*), dwarf blueberry (*Vaccinium myrsinites*), hog plum (*Ximenia americana*), paw paw (*Asimina obovata*), and others. Table 3 gives the percentage of cover for these and other shrub species at a representative sample site in each of the 2 phases of southern ridge sandhills.

Vine species occasionally present in this association include greenbrier (*Smilax auriculata*) and muscadine grape (*Vitis rotundifolia*). Common herbaceous species in the ground layer include the characteristic sandhill lupines (*Lupinus cumulicola* and *L. diffusus*), prairie clover (*Petalostemon feayi*), sensitive brier (*Schrankia floridana*), alicia (*Chapmannia floridana*),

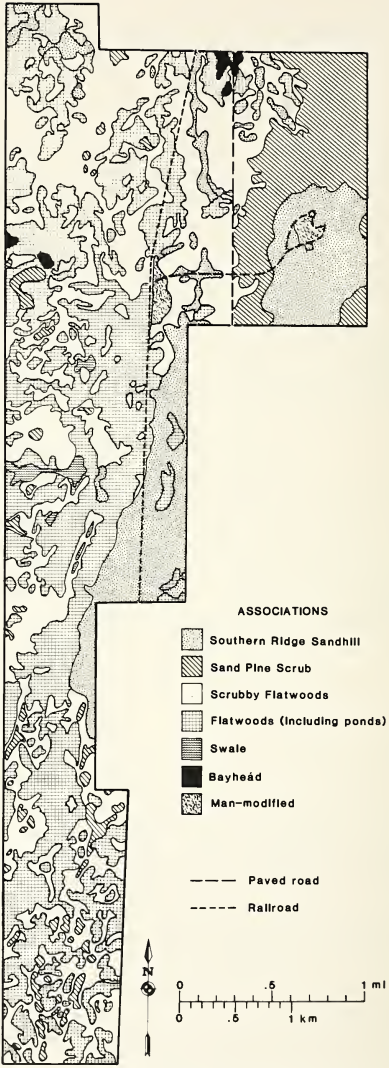

Fig. 2. General vegetation map of the Archbold Biological Station.

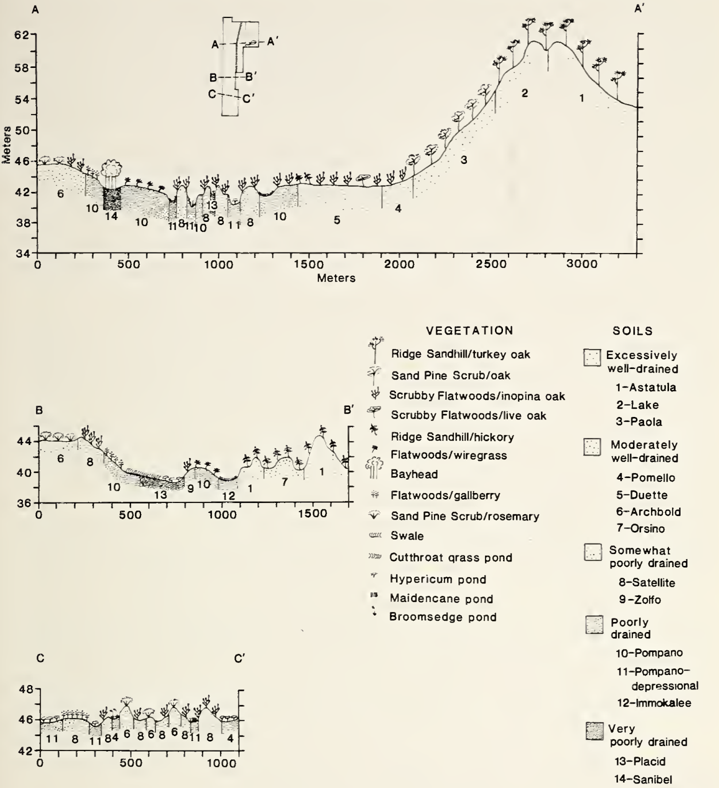

FIG. 3. Three east-west profiles across the Archbold Biological Station showing the relation of soils and vegetation to topography. The vertical exaggeration is 40X.

hoary peas (*Tephrosia chrysophylla*), yellow buttons (*Balduina angustifolia*), silk grass (*Heterotheca graminifolia*), gopher apple (*Licania michauxii*) and others shown in Table 3. Wiregrass (*Aristida stricta*), broom sedges (*Andropogon* spp.), and *Panicum patentifolium* are common, as are the sedges *Cyperus nashii* and *C. filiculmis* and the beak rush, *Rhynchospora megalocarpa*. Patches of lichens (*Cladonia* spp.) and spike moss (*Selaginella arenicola*) are common in bare sand areas. The canopy is generally open, allowing substantial amounts of sunlight to reach ground level. Bare patches of sand occur in the herbaceous layer, even in areas long unburned.

Southern ridge sandhill communities cover 14% (226 ha) of ABS (Table 2, Fig. 2). The turkey oak phase occupies the highest elevation of the study area, being restricted to the upper part of Red Hill generally above 53 m on the well-drained Astatula and Lake soils. The hickory phase occurs on ridges and knolls in the intraridge valley area (Fig. 2). It is typically found at elevations ranging from 38 to 40 m in the northern portion and at or above 44 m in the southern part of the property on Astatula and on the moderately well-drained Tavares and Orsino soils.

This vegetation type displays the most pronounced seasonal changes of any of the Lake Wales Ridge vegetation associations. The deciduous turkey oak and scrub hickory shed their leaves during November and December and usually do not flower and leaf out until late February or March.

Sand Pine Scrub: The term "scrub" is used here in a restricted sense to designate vegetation characterized by sand pine (*Pinus clausa*) as the dominant tree and with oaks or rosemary (*Ceratiola ericoides*) comprising a major component of the shrub layer. There is much variation in the stand density and canopy height of the sand pine depending on fire history and site characteristics, with long-unburned stands often having a closed canopy and a height of 10 or more meters. The height and density of shrubs is likewise fire- and site-dependent but can reach 3 or more meters and 100%, respectively. Although there is some gradation between them, 2 phases of scrub may be recognized: that with a predominantly evergreen oak understory and that dominated by rosemary, often in almost pure stands.

On the study area, the oak understory phase is a 3-layered community largely limited to the slopes of Red Hill. In addition to sand pine, characteristic woody species are myrtle oak, sand live oak, Chapman's oak, rusty lyonia, scrub hickory, hog plum, and silk bay (*Persea humilis*) (Table 3). Scrub palmetto and saw palmetto are common in the lower shrub layer.

Ground cover consists mostly of sprouts of the shrub layer species; herbs are scarce. The most common herbaceous species include beak rush (*Rhyncospora megalocarpa*), *Dicerandra frutescens*, milk peas (*Galactia* spp.), alicia, and *Panicum patentifolium*. Epiphytes such as Spanish moss (*Tillandsia usneoides*) and ball moss (*Tillandsia recurvata*), true mosses, and lichens are present. *Tillandsia recurvata* is most prevalent in mature scrub, whereas *T. usneoides* is more common in southern ridge sandhills.

With the exception of one relatively small tract along the western edge of the intraridge valley, the oak phase of the sand pine scrub association is represented by mature scrub unburned since 1926 or 1927. This mature scrub forms a distinct zone on the middle and lower slopes of Red Hill, mostly between 43 and 50 m, below the turkey oak phase of southern ridge sandhill. The location of this zone corresponds closely to the approximate position (46 m) of the former Okefenokee shoreline.

Most of the oak phase occurs on Paola soil. Small areas on the slopes of Red Hill are apparently on Astatula soil. However, because of the extensive intergradation between scrub and ridge sandhills in these areas, the line separating these associations is somewhat arbitrary. The stand of sand pine scrub on the west side of the valley is at an elevation of approximately 46-49 m on Archbold soil. This association covers 9% (143 ha) of ABS area (Table 2).

There is little seasonal change in the scrub association except the spring leaf turnover of the oak understory. The deciduous scrub hickory is sufficiently low in occurrence so as not to give scrub the characteristic "bare" appearance of the sandhill vegetation in winter. Light levels beneath the tree canopy in mature scrub are the lowest of any association, with the exception of bayheads.

The rosemary phase of sand pine scrub is an open community with the shrub layer dominated by even-aged stands of rosemary, varying in height up to nearly 3 m in mature stands (Table 3, Fig. 2). Rosemary often forms nearly pure stands, which may be interspersed with clumps of oaks, especially *Quercus inopina* (Johnson and Abrahamson, 1982). Sand pine is often scarce and may even be absent in small patches of this association. Consistently present, but making up less than 5% of the cover, are the palmettos *Serenoa repens* and *Sabal etonia* and the shrubs staggerbush (*Lyonia fruticosa*), rusty lyonia, tough buckthorn (*Bumelia tenax*), and silk bay. Herbaceous species are mostly perennial rosettes, many of which are endemic to this community. These include *Liatris ohlingerae*, *Eryngium cuneifolium*, *Hypericum cumulicola*, and *Lechea cernua*. In spring, *Stipulicida setacea* is conspicuous in rosemary scrub. The lichens *Cladonia evansi*, *C. leporina*, *C. prostrata*, and *C. subtenuis*, cover more of the area between the shrubs than does the herbaceous flora. In the first few years after fires the spike moss, *Selaginella arenicola*, is usually abundant, but after about 20 yr the *Cladonia* overgrow it and may eliminate it from the stand (Johnson, unpublished data).

The rosemary phase is confined to higher ridges and knolls in the valley area at elevations ranging from about 40-50 m. Most of the knolls or ridges with rosemary scrub in the southern part of the valley are 46 m or higher compared with about 38-40 m in the northern part (Fig. 2, Fig. 3). The rosemary phase is restricted to St. Lucie or Archbold soils, with most examples being on Archbold. Those examples of the rosemary phase occurring on St. Lucie soil are located at the northern end of the intraridge valley.

Five topograhic profiles showed rosemary scrub beginning 1-1.7 m above the maidencane (*Panicum hemitomon*) zone of seasonal ponds, which can be taken to be roughly the average level of the water table. Most of the 40 rosemary stands on higher knolls at ABS are only 1 ha or less in extent, but elsewhere in the region this association may cover extensive areas.

Scrubby Flatwoods: This shrubby association is predominantly evergreen with xeromorphic physiognomy. Tree presence is variable, consisting of an

TABLE 3. Percentage cover of species present at a sample site selected as representative for each vegetation association at ABS. Characteristic combinations of species for each vegetation phase are enclosed in boxes. Abbreviations of the associations are as follows: RSt = southern ridge sandhill-turkey oak phase, RSh = southern ridge sandhill-scrub hickory phase, SSo = sand pine scrub-oak understory phase, SSr = sand pine scrub-rosemary phase, SFi = scrubby flatwoods-inopina oak phase, FLw = flatwoods-wiregrass phase, FLp = flatwoods-palmetto phase, FLg = flatwoods-gallberry phase, SW = swale, and BH = bayhead. Data for RSt, SSo, Flp, and BH are from Givens et al. (in press) others from Abrahamson (1984a, b).

Characteristic Species	RSt	RSh	SSo	SSr	SFi	FLw	FLp	FLg	SW	BH
Quercus laevis	12	-	<1	-	-	-	-	-	-	-
Quercus geminata	18	10	8	<1	4	<1	3	-	-	-
Sabal etonia	11	20	26	1	8	<1	-	-	-	-
Quercus myrtifolia	20	36	24	-	-	<1	-	-	-	-
Carya floridana	12	9	20	-	-	-	-	-	-	-
Lyonia ferruginea	2	-	20	-	-	-	1	-	-	-
Pinus clausa	3	-	75	5	1	-	-	-	-	-
Ceratiola ericoides	-	-	-	55	-	-	-	-	-	-
Persea humilis	-	-	1	2	-	-	-	-	-	-
Quercus chapmanii	2	10	7	1	16	-	<1	-	-	-
Quercus inopina	-	<1	-	7	37	-	-	-	-	-
Aristida stricta	-	2	-	-	<1	54	-	1	-	-
Quercus minima	-	-	-	-	-	15	-	-	-	-
Hypericum reductum	-	-	-	-	-	5	-	<1	-	-
Serenoa repens	1	3	16	2	22	36	77	46	-	-
Ilex glabra	-	-	-	-	-	<1	27	17	4	-
Lyonia lucida	-	-	-	-	3	3	7	20	5	-
Panicum abscissum	-	-	-	-	-	-	-	86	100	-
Pinus elliottii	24	5	-	-	-	1	83	24	-	123
Gelsemium sempervirens	-	-	-	-	-	-	4	-	-	11
Gordonia lasianthus	-	-	-	-	-	-	2	-	-	36
Ilex cassine	-	-	-	-	-	-	<1	-	-	24
Magnolia virginiana	-	-	-	-	-	-	-	-	-	91
Osmunda cinnamonea	-	-	-	-	-	-	1	-	-	22
Persea borbonia	-	-	-	-	-	-	12	-	-	10
Other Species										
Andropogon spp.	<1	-	-	-	-	1	-	6	3	-
Asimina obovata	-	<1	<1	-	-	-	-	-	-	-
Asimina reticulata	-	-	-	-	-	<1	-	-	-	-
Balduina angustifolia	<1	-	-	-	-	-	-	-	-	-
Befaria racemosa	-	<1	-	-	-	<1	-	6	-	-
Bumelia tenax	-	<1	-	<1	-	-	-	-	-	-
Carphephorus paniculatus	-	-	-	-	-	<1	-	-	3	-
Chapmannia floridana	<1	-	<1	-	-	-	-	-	-	-
Cnidoscolus stimulosis	<1	-	-	-	-	-	-	-	-	-
Commelina erecta	<1	-	<1	-	-	-	-	-	-	-
Drosera capillaris	-	-	-	-	-	-	-	-	<1	-
Eriogonum longifolium	<1	-	-	-	-	-	-	-	-	-
Galactia spp.	1	-	2	-	-	-	-	-	-	-
Garberia fruticosa	-	3	-	-	-	-	15	-	-	-
Gaylussacia dumosa	<1	-	-	-	-	<1	-	1	1	-
Heterotheca graminifolia	<1	-	-	-	-	<1	-	-	<1	-
Houstonia procumbens	-	-	-	-	-	<1	-	-	-	-
Hypericum edisonianum	-	-	-	-	-	1	-	-	-	-
Hypericum tetrapetalum	-	-	-	-	-	<1	-	-	-	-
Ilex opaca	<1	-	<1	-	-	-	-	-	-	-

TABLE 3 continued

Species	RSt	RSh	SSo	SSr	SFi	FLw	FLp	FLg	SW	BH
Lachnanthes caroliniana	-	-	-	-	-	-	<1	-	-	-
Lachnocaulon anceps	-	-	-	-	-	3	-	-	-	-
Lechea cernua	-	-	-	<1	<1	-	-	-	-	-
Lechea deckertii	-	<1	-	-	<1	-	-	-	-	-
Licania michauxii	<1	2	<1	<1	<1	<1	-	-	-	-
Lupinus cumulicola	<1	-	-	-	-	-	-	-	-	-
Lyonia fruticosa	-	<1	-	-	2	2	-	3	2	-
Momordica charantia	-	-	-	-	-	-	1	-	-	-
Myrica cerifera	-	-	-	-	-	-	<1	-	-	4
Myrica cerifera var *pusilla*	-	-	-	-	2	-	<1	4	-	
Opuntia compressa	<1	-	-	1	-	-	-	-	-	-
Palafoxia feayi	<1	<1	<1	<1	<1	-	-	-	-	-
Panicum hemitomon	-	-	-	-	-	-	-	-	<1	-
Panicum patentifolium	<1	-	-	-	-	-	-	-	-	-
Panicum portoricense	-	-	-	-	-	<1	-	1	<1	-
Panicum sp.	-	-	<1	-	-	-	<1	-	-	-
Petalostemon feayi	-	<1	-	-	-	-	-	-	-	-
Pterocaulon pycnostachyum	-	-	-	-	-	<1	-	-	-	-
Polygala sp.	-	-	-	-	-	-	-	-	<1	-
Polygonella polygama	-	-	<1	-	1	-	-	-	-	-
Rhexia mariana	-	-	-	-	-	-	<1	-	<1	-
Rhus copallina	-	-	-	-	-	-	6	-	-	-
Rhychosia lewtonii	<1	-	-	-	-	-	-	-	-	-
Rhyncospora megalocarpa	-	<1	<1	-	<1	-	-	-	-	-
Schrankia floridana	-	<1	-	-	-	-	-	-	-	-
Selaginella arenicola	<1	-	-	-	-	-	-	-	-	-
Seriocarpus bifoliatus	-	-	-	-	<1	-	-	-	-	-
Sisyrinchium xerophyllum	<1	-	-	-	-	-	-	-	-	-
Smilax auriculata	-	<1	-	1	<1	-	-	-	-	-
Smilax sp.	<1	-	2	-	-	-	4	-	-	-
Syngonanthus flavidulus	-	-	-	-	-	-	-	<1	<1	-
Tephrosia chrysophylla	<1	-	-	-	-	-	-	-	-	-
Tradescantia sp.	-	-	-	<1	-	-	-	-	-	-
Tragia linearifolia	<1	-	-	-	-	-	-	-	-	-
Vaccinium corymbosum	-	-	-	-	-	-	<1	-	-	-
Vaccinium darrowii	-	-	-	-	-	<1	-	-	-	-
Vaccinium myrsinites	<1	<1	<1	-	<1	<1	-	5	5	-
Vitis rotundifolia	<1	-	10	-	-	-	4	-	-	3
Ximenia americana	-	<1	1	2	-	-	23	-	-	32
Xyris spp.	-	-	-	-	-	<1	-	-	<1	-

occasional south Florida slash pine or sand pine. The average height of most shrubs is 1-2 m, but this will vary with the local site conditions (moisture and perhaps nutrients) and time elapsed since the last fire. Herbaceous vegetation is sparse, consisting of wiregrass and forbs. (Table 3, Fig. 2), but *Cladonia* lichen cover and *Selaginella* cover can be considerable in all but recently burned areas.

As is the case with rosemary phase of sand pine scrub, the dominant species of scrubby flatwoods show convergence in their xeromorphic adaptations which include small, sclerophyllous leaves that are often revolute and/or linear. The leaves of many species (e.g., *Quercus geminata*, *Lyonia fruticosa*, *L. ferruginea*, *Bumelia tenax*, *Persea humilis*) have pubescent undersides.

Floristically, the scrubby flatwoods are intermediate between the oak understory phase of sand pine scrub and flatwoods (Table 3) associations. Scrubby flatwoods communities differ from the typical flatwoods associations in that they occur on well-drained soils where there is no standing water even under extremely wet conditions. They differ from typical sand pine scrub associations in that their soils tend to have a higher water table.

Quercus inopina is the most charcteristic species of this association (Table 3), although sand live oak or Chapman's oak may dominate at particular sites. Sand live oak forms dense stands in the slightly less elevated portions of scrubby flatwoods. Both saw and scrub palmetto are common, with saw palmetto reaching its highest densities in less elevated and scrub palmetto in more elevated, sites. Shrub species of scrubby flatwoods shared by less well-drained flatwoods sites include fetterbush (*Lyonia lucida*), tar flower (*Befaria racemosa*), blueberries (*Vaccinium myrsinites* and *V. darrowii*), and staggerbush. *Palafoxia feayi* is conspicuous in scrubby flatwoods areas, frequently extending above the general shrub canopy. Gopher apple (*Licania michauxii*), pinweeds (*Lechea cernua* and *L. deckertii*), and frostweed (*Helianthemum nashii*) commonly form the ground cover in the more open areas; greenbriar (*Smilax auriculata*) is a frequent climber.

Although there is considerable gradation in the physiognomy and species composition of scrubby flatwoods on the ABS, 3 phases can be recognized: inopina oak, sand live oak, and human-created Bahia grass phase. The most extensive phase is that dominated by inopina oak. In areas of slightly lower elevation, sand live oak and saw palmetto come to dominate at the expense of inopina oak, Chapman's oak, and scrub palmetto. If unburned for 20 yr or more, sand live oak has the potential to become a small tree in moister sites. Where this occurs in scrubby flatwoods, a sand live oak thicket develops, forming a dense canopy with little understory except saw palmetto. The Bahia grass phase of scrubby flatwoods has ground cover of the introduced Bahia grass (*Paspalum notatum*) with scattered saw palmetto. This phase is confined to a small area on the edge of the ABS property where Bahia grass was artificially seeded into disturbed ground. The grass does not appear to be invading adjacent undisturbed areas.

Scrubby flatwoods, which make up 37% (587 ha, Table 2) of ABS area, occur at elevations intermediate between scrub or southern ridge sandhills associations and flatwoods associations. The overall elevational range of this association is from about 38-46 m, with most stands occurring from 40-43 m. As in the case with the previous associations, elevations at which scrubby flatwoods occur tend to be higher (43-44 m) in the southern part of the valley than in the northern part (40 m). Although observations indicate that at any given location on the study area the inopina oak phase of scrubby flatwoods tends to occur on more elevated sites than the live oak phase, the contour interval of the standard U.S.G.S. quadrangle is too large to show this relationship.

The inopina phase of scrubby flatwoods occurs most frequently on Satellite soil, except at the lower elevations in the northernmost end of the valley where it is found primarily on Duette soil. This phase is also relatively frequent on Zolfo soil and several examples, including some fairly extensive areas, occur on St. Lucie and Archbold soils. Areas of live oak phase of scrubby flatwoods are too small to be confidently correlated with soil type on the basis of present data.

Scrubby flatwoods show only slight seasonal change. Flowering and leafing of the oaks are staggered by species. *Quercus myrtifolia*, occurring infrequently in this association, typically flowers and leafs before *Q. inopina* (Johnson and Abrahamson, 1982). The flowering of *Q. chapmanii* and *Q. geminata* falls between the 2 previous species. Each of these species drops its leaves, flowers, and produces new leaves within several weeks during March, April, and May; thus there are never extended periods of leaflessness, although during particularly droughty springs this association may have a barren, leafless aspect. Flowering of other scrubby flatwoods species is well-distributed throughout spring, summer, and fall, although the spring flowering species (i.e., *Vaccinium*, *Gaylussacia*, *Lyonia*, *Befaria*, *Ilex*) and fall bloomers (*Garberia*, *Polygonella*) are most conspicuous.

Flatwoods: The flatwoods association occurs on more poorly drained soils which, depending on rainfall, may vary from very dry to covered by standing water. This association ranges from open savannah-like aspect with saw palmettos, wiregrass, and scattered south Florida slash pines or occasional longleaf pines to dense pine stands with thick shrub cover. Typically, the south Florida slash pines are widely scattered in areas of flat terrain, but may form dense stands on the borders of seasonal ponds or in lower areas (Table 3, Fig. 2). The amount of light reaching ground level is variable, depending upon the development of the slash pine and/or shrub canopy, but is typically less than in scrubby flatwoods. Numerous species of shrubs and herbs comprise the ground cover. Under wetter conditions and with the absence of fire, the shrub layer can become very dense. Flatwoods comprise 25% (398 ha, Table 2) of the ABS area.

Flatwoods on the study area range from types with relatively dry wiregrass ground cover to those on more poorly drained soils consisting of dense slash pine with fern understory. Although the various types form a continuum, 5 relatively distinct phases may be recognized as follows: wiregrass flatwoods, cutthroat grass (*Panicum abscissum*) flatwoods, palmetto flatwoods, gallberry (*Ilex glabra*) flatwoods, and fern/slash pine (*Woodwardia virginica* and *Osmunda cinnamonea*/*P. elliottii* var. *densa*) flatwoods.

Wiregrass flatwoods are characterized by wiregrass which comprises >50% ground cover, saw palmetto which is typically dwarfed as compared to its stature in other flatwoods and dwarf St. Johns-wort (*Hypericum reductum*). Other shrubs include runner oak (*Quercus minima*), dwarf huckleberry, fetterbush, dwarf wax myrtle (*Myrica cerifera* var. *pusilla*), staggerbush, blueberries, gopher apple, tar flower, and gallberry. Numerous herbaceous species are characteristically found in this association. These include bog buttons (*Lachnocaulon anceps* and *L. minus*), blackroot (*Pterocaulon pycnostachyum*), false foxglove (*Gerardia fasciculata*), white topped aster (*Seriocarpus bifoliatus*), and yellow-eyed grasses (*Xyris* spp.).

Cutthroat grass flatwoods differ from the preceding in the dominant grass cover and the greater robustness of the saw palmetto. Runner oak, dwarf St. John's-wort, and dwarf wax myrtle are less prevalent, while fetterbush and south Florida slash pine tend to be more frequent.

The palmetto flatwoods phase is characterized by a shrub layer dominated by dense, vigorous stands of saw palmetto 1-2 m tall and an overstory of slash pine varying from open to dense. Although some examples of this phase have a shrub layer composed almost entirely of palmetto, others contain gallberry and fetterbush in varying abundance. Scrub palmetto also occurs in this phase, typically in the drier parts of the moisture gradient. This phase often forms a distinct zone around seasonal ponds, with an abrupt transition from palmetto to the vegetation of the pond. More extensive areas of this phase, not associated with ponds, also occur in suitable sites.

The gallberry-fetterbush flatwoods phase possesses a well-developed and diverse shrub layer, either with or without south Florida slash pine. Fetterbush and gallberry are especially abundant. Tarflower and staggerbush (*Lyonia fruticosa*) are also conspicuous elements. Saw palmetto often attains high coverage values and large size. Within 1-2 yr following fire, dwarf huckleberry and shiny blueberry reach high shoot densities and frequencies, but are shaded out relatively quickly as the taller shrubs overtop them.

The fern flatwoods phase contrasts with other types of flatwoods in having abundant ferns in the understory. The chain fern dominates, with scattered areas of cinnamon fern and some royal fern (*Osmunda regalis*). Cutthroat grass is also abundant, with beardgrasses (*Andropogon glomeratus*, *A. capillipes*, *A. brachystachys*) and maidencane (*Panicum hemitomon*) present. In depressions, hat pins (*Eriocaulon compressum*), arrow arum (*Peltandra virginica*), and arrowhead (*Sagittaria graminea*) are found. The surface of the ground is extremely hummocky in this phase. Common shrubs and broad-leaved trees include wax myrtle (*Myrica cerifera*), blackgum (*Nyssa biflora*), red maple (*Acer rubrum*), and loblolly bay (*Gordonia lasianthus*). These species are typical of hardwood swamps, suggesting that with fire exclusion this phase would eventually develop into such an association. There is pronounced seasonal change in this phase due to the deciduous nature of the dominant chain fern and other herbaceous components.

Flatwoods occur over approximately the same range of elevation as scrubby flatwoods, although in the same area they invariably occupy lower sites than do scrubby flatwoods. The presently available topographic data are too coarse-grained to determine elevational limits of the various phases of this association. However, observation suggests that in any given area the phases form an elevational sequence as follows: fern < cutthroat < palmetto < gallberry < wiregrass.

Of 8 soil types (Pompano, Immokalee, Immokalee depressional, Placid, Basinger, Myakka, Daytona, Sellers) supporting flatwoods associations, Pompano and Immokalee are most extensively associated with this vegetation type. Wiregrass, gallberry, and palmetto phases of flatwoods are most commonly found on Pompano soils, whereas Immokalee soils are most characteristic of the cutthroat grass phase. The gallberry and palmetto phases also frequently occur on Immokalee soils. The fern phase of flatwoods is found on the more poorly drained Sellers soil.

Swale: This is an association dominated by grasses and several shrub species occupying low-lying stretches of land. Notable is the nearly complete absence of saw palmetto and south Florida slash pine. Cutthroat grass covers nearly 100% of the ground. Broomsedges (*Andropogon brachystachys*, *A. capillipes*, *A. glomeratus*) and sedges (*Cyperus distinctus*, *C. odoratus*) are occasional to common. Other herbaceous species often present in considerable numbers after fire or in wetter years include milkworts (*Polygala nana*, *P. rugelii*), sundews (*Drosera capillaris*), Burmannias (*Burmannia biflora* and *B. capitata*), Carphephorus (*Carphephorus paniculatus*), meadow beauty (*Rhexia* spp.), bantum buttons (*Syngonanthus flavidulus*), and yellow-eyed grasses. The shrubby species are scattered and generally <1 m in height and consist mainly of fetterbush, gallberry, dwarf blueberry, dwarf huckleberry, dwarf wax myrtle, and staggerbush (Table 3, Fig. 2). This association occupies sites ranging about 43-46 m in elevation. The typical soils of this association are Sellers and Placid, although, as mapped, some is found on Pompano depressional.

Bayhead: Laessle (1942) described "bayhead" as an association of broad-leaved evergreen trees growing in strongly acid muck soils subject to periodic flooding and usually surrounded by flatwoods or other associations. The tree canopy is well-developed, producing a shady understory. Characteristic trees include loblolly bay (*Gordonia lasianthus*), red bay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), and slash pine (Table 3, Fig. 2). The slash pine may occur either as a relict of an earlier stage or because of intermediate edaphic conditions between bayhead and palmetto flatwoods. The larger slash pines are found in the interior portion of the bayhead with smaller trees forming the periphery. The shrubby undergrowth includes wax myrtle, dahoon holly (*Ilex cassine*), gallberry, fetterbush, maleberry (*Lyonia ligustrina*), and high bush blueberry (*Vaccinium corymbosum*). Common climbers are yellow jasmine (*Gelsemium sempervirens*), muscadine grape, greenbrier, catbrier (*Smilax laurifolia*), and Virginia creeper (*Parthenocissus quinquefolia*). These species often form a dense thicket around the periphery of the bayhead and are less abundant in the interior sections. There are few herbaceous species in the most densely shaded areas, but cinnamon fern, beak rush (*Rhyncospora microcarpa*), and bachelor's buttons (*Eriocaulon decangulare*) occur in slightly more open areas. The epiphyte *Tillandsia utriculata* is occasional on large trees. Bayheads are strongly evergreen, showing little seasonal change. Flowering is primarily a spring phenomenon with the peak occurring from February through May.

This association is found at elevations ranging about 38-43 m and accounts for 0.35% of ABS area (5.52 ha, Table 2). Two of the 3 bayheads included in the study area are on Sanibel soil and the third on Pompano depressional. Although a layer of muck characteristic of bayhead soils is present on the latter soil, it is thinner than that of Sanibel soil.

Seasonal Ponds: The intraridge valley portion of ABS is liberally pockmarked with seasonal ponds: rounded or irregularly shaped, shallow depressions from tens to hundreds of meters in diameter. Taken together, ponds cover 169 ha or 10% of the ABS area (Table 2). These ponds vary extensively in the nature of their vegetation, which in turn reflects the depth of the ponds and type of soil. The hydroperiod of the ponds is extremely variable depending upon their elevation, basin characteristics, and rainfall patterns. None is permanently flooded, some have water every summer and for longer periods in wetter years, and some have water only in the wettest years.

Common features of most of the ponds are a ring of saw palmetto surrounding them and the zonal pattern of their contained vegetation. The major species associated with seasonal ponds include maidencane, Edison's hypericum (*Hypericum edisonianum*), cutthroat grass, and broomsedge (*Andropogon brachystachys*). These species are zoned according to depth, which in 20 ponds sampled ranged from 20-120 cm below the saw palmetto border (Table 4). No single pond contains all of the zones discussed below and many ponds are unzoned. The most common sequences encountered from center to edge are: 1) maidencane/ *Hypericum* / cutthroat grass in the deeper ponds and in the shallower ponds either 2) *Hypericum* / broomsedge or 3) pure cutthroat grass.

In the center of the deepest ponds there is no emergent vegetation but only standing water during periods of flooding. The next deepest zone, which is usually at least moist, if not covered by standing water during the winter dry season, is dominated by a sparse stand of maidencane often associated with *Xyris fimbrata* and *Eriocaulon decangulare* and a continuous ground cover of *Sphagnum* spp. The next higher zone is characterized by the rhizomatous *Hypericum edisonianum* which may form dense, nearly pure stands in the deeper end of the zone and become sparser in the shallower end. Yellow-eyed grass (*Xyris elliottii*) or blue maidencane (*Amphicarpon muhlenbergianum*) may form a continuous cover in the shallow

TABLE 4. Percentage cover of species present in samples selected as representative of each seasonal pond type at ABS.

	Zones			
	Maidencane (11 stands)	Hypericum (14 stands)	Cutthroat Grass (9 stands)	Andropogon (3 stands)
Number of meters sampled	171	176	139	46
Water depth (cm; March 1980)*	+25	—4	—25	—40
pH	3.5	3.8	3.6	4.1
Characteristic Species:				
Panicum hemitomon	26	<1		
Sphagnum macrophyllum	10	2	1	
S. cuspidatum	4			
S. fitzgeraldii	5		2	
S. perichaetiale	5			
Eriocaulon compressum	2			
Xyris fimbriata	2	1		
Polygala cymosa	<1			
Hypericum edisonianum	6	18	5	<1
Xyris elliottii	<1	7	1	3
Andropogon capillipes	<1	4	1	2
Fuirena scirpoides	2	3	<1	<1
Eriocaulon decangulare	1	2	<1	
Amphicarpon muhlenbergianum	1	2	<1	<1
Panicum abscissum	<1	<1	72	
Andropogon stolonifera			4	
Woodwardia virginica	1	1	2	
Andropogon brachystachys				15
Syngonanthus flavidulus	3	11	9	22
Xyris brevifolia			1	8
Utricularia subulata		<1	1	2
Rhynchospora divergens				1
Other species				
Drosera capillaris		<1	<1	2
Eupatorium capillaceum		1	<1	<1
Eupatorium recurvans		<1		1
Hypericum fasciculatum	<1			
Lacnanthes caroliniana	1	<1		
Lachnocaulon anceps				2
Panicum portoricense		4		2
Panicum tenerum	<1	1		
Paspalum vaginatum		1	<1	
Rhexia mariana	1	<1		
Rhynchospora cephalantha	1	1	2	<1
Spartina bakeri	1	2	2	
Utricularia purpurea	<1			
Xyris jupicai		<1		
Total Number of Species	24	24	19	16

* + = standing water above ground surface; — = below ground surface

end of the zone. The species composition and vegetative cover of this zone are the most variable of any, with many of the dominants ranging into deeper and shallower zones as well (Table 4). This zone usually dries out during the winter dry season. The marginal zone of the ponds may be dominated either by a dense mat of cutthroat grass or by a sparse stand of broomsedge with small herbs which appears as a bare white sand margin on aerial photographs. The reason for such a striking difference in vegetation at the same relative elevation is not obvious. Two other species occasionally form pure stands of significant area in the ponds: redroot (*Lachnanthes caroliniana*) which may dominate in the maidencane zone, and tall cordgrass (*Spartina bakerii*) which occurs in the drier portions of the *Hypericum* zone.

Phenology of seasonal pond species is keyed to hydroperiod. The shorter species (e.g., *Eriocaulon compressum*, *Xyris elliottii*, *Syngonanthus flavidulus*, and *Andropogon capillipes*) flower in the spring before the water level rises. Taller species (e.g., *Xyris fimbriata*, *Eriocaulon decangulare*, and *Andropogon brachystachys*) flower in summer and fall when water levels may be up to 0.8 m higher.

The soils of seasonal ponds include Pompano, Pompano depressional, Immokalee, Immokalee depressional, Basinger, Basinger depressional, Myakka depressional, Placid, and Sanibel. Soils in which the various seasonal pond species most frequently occur are as follows: broomsedge -Pompano depressional and Basinger; cutthroat - Pompano depressional and Myakka depressional; *Hypericum* - Pompano depressional, Immokalee depressional, and Placid; *Spartina* - Immokalee depressional; redroot -Placid; maidencane - Pompano depressional and Placid.

Plant Species Diversity: Species diversity, evenness, species richness (number of species present), and the significance of the diversity indices are in Tables 5 and 6. Of the stands sampled, the turkey oak phase of the southern ridge sandhills and old-growth scrubby flatwoods were the most diverse associations, yielding the highest species richness with 33 and 30 species, respectively (Table 5). Both associations had intermediate levels of evenness compared to other associations. The scrub hickory phase of southern ridge sandhills, oak understory phase of sand pine scrub, wiregrass flatwoods, palmetto flatwoods, and recently burned scrubby flatwoods had intermediate plant species diversity and species richness ranging from a low of 18 for scrubby flatwoods to a high of 29 for wiregrass flatwoods. Evenness was variable for this group of associations, with intermediate values for most associations but a relatively low value for wiregrass flatwoods.

Gallberry/fetterbush flatwoods, bayhead, and cutthroat grass flatwoods had lower species diversity than the preceding associations. Species richness was relatively low for gallberry/fetterbush flatwoods with the lowest value (11) for the bayhead. Cutthroat grass flatwoods showed intermediate species richness but relatively low evenness, while the bayhead sampled had the

TABLE 5. Shannon-Weaver diversity (H′), evenness (e_s), and species richness (S) indices based on percentage cover for plant species from representative stands of each habitat type except seasonal ponds. Associations are listed in order of the Shannon-Weaver diversity indices, values with the same letter are not statistically significant at the 95% level as determined at Student's t-test (Hutcheson, 1970).

Association	H′	e_s	S
Southern Ridge Sandhills-turkey oak phase (RSt)	2.66 a	0.23	33
Scrubby Flatwoods-old growth (SFg)	2.56 ab	0.26	30
Southern Ridge Sandhills-hickory phase (RSh)	2.32 bc	0.23	23
Sand Pine Scrub-oak understory phase (SSo)	2.25 c	0.23	24
Flatwoods-wiregrass phase (FLw)	2.15 cd	0.13	29
Flatwoods-palmetto thicket/pond border phase (FLp)	2.06 ce	0.23	21
Scrubby Flatwoods (SFi)	1.99 cef	0.23	18
Flatwoods-gallberry/fetterbush phase (FLg)	1.86 def	0.26	16
Bayhead (BH)	1.83 f	0.42	11
Flatwoods-cutthroat grass phase (FLc)	1.70 fg	0.12	21
Sand Pine Scrub-rosemary phase (SSr)	1.45 gh	0.11	16
Swale (SW)	1.23 h	0.09	17

TABLE 6. Shannon-Weaver diversity (H′), evenness (e_s), and species richness (S) indices based on percentage cover for plant species from representative stands of each seasonal pond zone. Zones are listed in topographic order from lowest to highest elevation, values with the same letter are not statistically significant at the 95% level as determined by Student's t-test (Hutcheson, 1970).

Seasonal Pond Zone	H′	e_s	S
Maidencane	2.28 ab	0.18	24
Hypericum	2.34 a	0.20	24
Cutthroat grass	1.31	0.09	19
Andropogon	1.88 b	0.23	16

highest evenness. Thus, although the bayhead had few species, the abundances were rather evenly distributed among those species.

Rosemary phase of sand pine scrub and the swale had lowest plant species diversity as a result of high dominance by 1 species and relatively low species richness values (Table 5).

Species diversity was determined for the seasonal pond zones using percentage cover data. The maidencane and *Hypericum* zones had the highest species diversity (Table 6). These 2 zones also had the highest species richness with intermediate levels of evenness. The *Andropogon* zone ranked third in species diversity and, although it had the lowest species richness, it possessed the highest evenness of the seasonal pond zones sampled. The cutthroat grass zone had the lowest species diversity and evenness, resulting from the extreme dominance by cutthroat grass.

Community Similarity: Table 7 presents pair-wise association comparisons for all but the seasonal pond zones. Among the 6 vegetation associations on the study area, similarities are not higher than 0.61, with the excep-

TABLE 7. Horn's Indices, R_o, of community similarity (based on percentage cover) for all sites except seasonal ponds. Abbreviations for associations are as in Table 3.

	RSt	RSh	SSr	SSo	SFig[a]	SFi	FLw	FLc	FLg	FLp	SW	BH
RSt	1.0											
RSh	0.69	1.0										
SSr	0.15	0.19	1.0									
SSo	0.60	0.61	0.23	1.0								
SFi-g	0.57	0.59	0.26	0.52	1.0							
SFi	0.25	0.46	0.34	0.39	0.75	1.0						
FLw	0.14	0.23	0.08	0.19	0.34	0.35	1.0					
FLc	0.29	0.30	0.10	0.27	0.55	0.48	0.64	1.0				
FLg	0.20	0.16	0.05	0.12	0.36	0.29	0.41	0.75	1.0			
FLp	0.32	0.23	0.10	0.21	0.44	0.30	0.33	0.64	0.54	1.0		
SW	0.04	0.03	0.00	0.01	0.09	0.07	0.14	0.30	0.74	0.08	1.0	
BH	0.24	0.10	0.04	0.03	0.11	0.00	0.02	0.17	0.17	0.51	0.00	1.0

[a] SFi-g—scrubby flatwoods-inopina oak phase (long unburned).

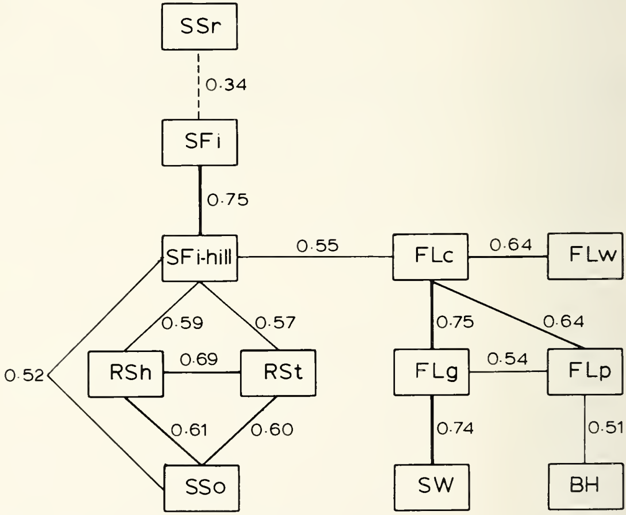

FIG. 4. Community (similarity diagram using Horn's indices, R_0, (based on percentage cover) greater than 0.50 with the exception of the rosemary scrub). Horn's index is based on both species presence and the relative abundances, ranging from 1.0 if all species are common to both associations and their abundances are equal to 0.0 if no species are common to both samples. Abbreviations of the associations are as follows. RSt = southern ridge sandhill-turkey oak phase, RSh = southern ridge sandhill-scrub hickory phase, SSo = sand pine scrub-oak understory phase, SSr = sand pine scrub-rosemary phase, SFi = scrubby flatwoods-inopina oak phase, FLw = flatwoods-wire grass phase, Flp = flatwoods-palmetto phase, FLg = flatwoods-gallberry phase, SW = swale, and BH = bayhead. Data for RSt, SSo, Flp, and BH are from Givens et al. data for others from Abrahamson (1984a, b).

tion of the 0.74 similarity between swale and gallberry flatwoods. However the swale stand is not very similar to any other flatwoods types and is thus kept separate. Within the major associations, similarities between vegetation phases range from 0.33-0.75, the exception in this case is the rosemary scrub which has a very low similarity (0.23) with oak understory scrub. In fact, rosemary scrub shows more similarity to scrubby flatwoods (0.34) than to oak scrub. This may, in part, reflect the very different fire histories of the oak understory scrub and the rosemary scrub stands. Elsewhere in Florida sand pine is taken to indicate scrub and we have followed that convention here.

Fig. 4 diagrams community similarity relationships among the vegetation types. All types having Horn's indices (based on percentage cover) greater than 0.50 (with the exception of the rosemary scrub) are connected by a line. When this is done 2 clusters of vegetation associations appear: (1)those of the well-drained sites (scrubs, scrubby flatwoods, and southern ridge sandhills) and (2) those of the poorly drained sites (flatwoods, swales, and bayheads). Scrubby flatwoods and cutthroat grass flatwoods bridge the gap between the 2 main clusters, reflecting, in part, the transitional topographic position of scrubby flatwoods between the better-drained scrubs and sandhills and the more poorly-drained flatwoods, swale, and bayhead sites. The diagram also brings out those types with close similarity to no (rosemary scrub) or only 1 (wiregrass flatwoods, swale, and bayhead) other type in contrast to those associations closely similiar to several other types (southern ridge sandhills, sand pine scrub-oak understory phase, scrubby flatwoods, cutthroat grass flatwoods, gallberry flatwoods, and palmetto flatwoods).

Table 8 gives the Horn's indices for the seasonal pond zones based on percentage cover data. The topographic order of these zones, starting from the lowest elevation, is: maidencane, *Hypericum*, cutthroat grass, and broomsedge. The community similarity values follow this order in that adjacent zones are most similar to one another and more distant zones least similar. The one exception was the broomsedge zone, which had greater similarity to the *Hypericum* zone than the cutthroat grass zone due to the high dominance by cutthroat grass in the latter zone.

TABLE 8. Horn's Indices, R_0, of community similarity for seasonal pond zones based on percentage cover data. Abbreviations for the pond zones are as follows: SPm = maidencane zone, SPh = hypericum zone, SPc = cutthroat grass zone, SPb = broomsedge zone.

	SPm	SPh	SPc	SPb
SPm	1.0			
SPh	0.46	1.0		
SPc	0.25	0.39	1.0	
SPb	0.13	0.45	0.27	1.0

TABLE 9. Annual means and ranges of monthly mean maximum and minimum air and soil temperatures (°C) in five long-unburned vegetation associations from 1975 to 1980.

	Air Temperature at 30 cm Height				Soil Temperature at 5 cm Depth			
	Maximum		Minimum		Maximum		Minimum	
Association	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Ridge sandhills (turkey oak phase)	34.5	29.1-38.0	12.0	2.7-20.1	27.6	21.1-32.7	19.1	11.8-24.5
Sand pine scrub (oak phase)	32.0	26.9-35.5	12.5	3.2-21.0	23.0	18.4-26.3	20.3	15.0-24.7
Scrubby flatwoods (inopina phase)	35.4	29.4-39.5	9.1	—1.0-18.5	27.0	20.9-31.3	18.9	11.8-24.2
Flatwoods (palmetto)	34.2	27.7-39.4	10.9	1.9-19.2	22.9	19.1-26.4	19.3	14.1-23.7
Bayhead	29.3	25.0-32.1	11.2	2.3-19.1	22.1	19.0-24.4	20.1	15.2-24.0

Microclimate Characteristics of Vegetation Types: Annual means and ranges of monthly means of maximum and minimum air and soil temperatures in long unburned examples of 5 of the associations for the 5-yr period 1975-1980 are in Table 9. Based on 1 microclimate recording station in each association, sand pine scrub and bayhead had the most stable microclimates, as reflected in the smaller differences between annual mean maximum and minimum temperatures in these associations compared to the others. Soil temperatures of sand pine scrub and bayhead were not as high in summer or as low in winter as in scrubby flatwoods, southern ridge sandhills, and flatwoods. Bayhead had the lowest daily temperature fluctuation of any association. For example, the difference between monthly maximum and minimum bayhead soil temperatures from June through September ranged from 0-0.8°C compared to 6.6-8.8°C in southern ridge sandhills. Flatwoods and scrubby flatwoods had the most extreme air temperatures and scrubby flatwoods and southern ridge sandhills the widest range of soil temperatures. Based on air and soil temperatures combined, the 5 vegetation types ranked as follows in stability of microclimate: bayhead > sand pine scrub > flatwoods > southern ridge sandhills > scrubby flatwoods.

Although the differences in air and soil temperature between vegetation associations are undoubtedly mainly reflective of the plant cover per se, topographic features probably also contributed to the observed microclimatic differences. As the ridge sandhill site was near the highest elevation on ABS while the other sites were lower, settling of cooler air into lower areas on windless nights might have contributed to higher minimum (night-time) air temperatures at the sandhill site.

It should also be strongly emphasized that the sand pine scrub site was a mature stand with a closed to nearly-closed canopy, well-developed shrub layer, and heavy litter layer, all of which account for its moderate and relatively stable microclimate. Earlier successional scrubs would be expected to be more similar to the scrubby flatwoods or southen ridge sandhill sites in their air and soil temperature characteristics.

Soil Moisture: Soil moisture determinations in different vegetation associations at different seasons are in Tables 10 and 11. Because samples in the intraridge valley and Red hill sections of ABS were taken in different years, the values are not directly comparable. In both cases, however, the relationship of soil moisture to vegetation type was clear-cut, as was the pronounced seasonal change from the wet summer to dry winter and early spring periods. The data for the hill section show that, although the water table of scrubby flatwoods soils is much shallower than that of either ridge sandhill or sand pine scrub, the scrubby flatwoods soils become just as droughty in the upper layer as those of the other 2 associations. The intraridge valley samples indicate that rosemary phase sand pine scrub is associated with the driest sites, whereas ridge sandhill-hickory phase and scrubby flatwoods soils tend to be somewhat moister. The data confirm that

TABLE 10. Soil moisture (% by weight) in vegetation types in the hill section (southern ridge sandhill, sand pine scrub) and eastern edge of the intraridge valley of the ABS in August 1970, January 1971, and April 1971. Samples, exclusive of litter, taken to 25.4 cm depth. Three subsamples taken at each station. Samples in each period taken at same stations.

Association and Phase	N Stations	August	January	April
Ridge sandhill-turkey oak	5	6.2(4.4-10.9)	1.8(1.2-2.2)	1.2(0.6-1.5)
Mature sand pine scrub-oak (closed canopy)	5	6.1(5.0-7.0)	2.5(1.8-3.0)	1.4(0.7-2.3)
Scrubby flatwoods-inopina oak	9	5.8(4.2-6.7)	2.1(1.6-2.8)	0.9(0.1-2.1)
Flatwoods-palmetto	4	35.4(24.9-46.6)	27.6(16.1-41.8)	
Bayhead	5	50.9(34.7-76.2)	57.2(35.8-77.7)	55.1(40.2-75.1)

TABLE 11. Soil moisture (% by weight) in vegetation types in the intraridge valley portion of the ABS in September 1980 (mean of 3 dates) and January 1981.

Association and Phase	N Stations	September	January
Ridge sandhill-hickory	2	4.2(3.0-6.4)	2.5(2.1-2.8)
Sand Pine scrub-rosemary	2	3.5(2.7-4.7)	1.5(1.3-1.6)
Scrubby flatwoods-inopina	5	4.1(2.9-6.2)	1.7(1.3-2.0)
Scrubby flatwoods-live oak	2	4.9(3.4-6.3)	2.1(1.9-2.2)
Flatwoods-wiregrass	4	5.2(4.1-7.3)	2.8(2.5-3.3)
Flatwoods-cutthroat	2	5.4(3.7-7.7)	2.6(2.3-2.8)
Flatwoods-gallberry	1	11.9(11.0-13.3)	7.0
Swale	1	14.6(11.7-15.0)	6.3
Seasonal pond-*Hypericum*	2	3.7(3.0-5.2)	2.0(1.9-2.1)
Seasonal pond-maidencane	1	20.8(18.4-23.7)	10.4

the live oak phase scrubby flatwoods occupies moister sites than inopina oak dominated areas. Wiregrass flatwoods are the driest of the 3 flatwoods phases sampled.

Soil pH and Nutrients: Measurements of pH and soil nutrients were obtained at 21 sites representative of all the major vegetation associations and most of the phases recognized under each (Table 12). In general, there were no clear-cut trends between pH and nutrient levels and vegetative patterns. However, as the sampling was done on a relatively gross level, more intensive analysis may reveal correlations between soil chemistry, and vegetation or site history (e.g., time since burning). On the basis of present data, drainage characteristics seem to be a more important determinant of vegetation type than pH or major soil nutrient concentrations.

Soil pH values ranged from 3.5-5.6 (mean: 4.6). The minimum and maximum values were in gallberry flatwoods and ridge sandhills hickory phase sites, respectively. Flatwoods had the greatest range of pH of any major vegetation association. There was considerable variation in pH within the same vegetative phase as well as within major associations, and no obvious trends were evident. Where the same phase of a given major association was sampled in both the intraridge valley and in the hill sections, the hill site tended to have a higher pH.

As in the case of pH, there was a general tendency for sites in the hill section to have higher nutrient levels than the same vegetation phase in the intraridge valley section. This may be a consequence of the long absence of fire in the hill section of ABS. Of the vegetation types sampled, the palmetto flatwoods site had the highest levels of all nutrients.

Historical Antecedents of the Present Vegetation: From a geological perspective, the vegetation of the southern Lake Wales Ridge appears to

TABLE 12. Representative soil pH and nutrient levels in major vegetative types based on samples from upper 25.4 cm. Letters in parentheses following vegetation type refer to hill (H) and intraridge valley (V) sections. Soil samples from the hill section were obtained in September 1969, those from the valley section in January 1977. Hill section values are based on samples from 1 to 6 sites representative of the particular vegetation. Where more than 1 site was sampled, mean values are given. Values from the valley section are from 10 pooled subsamples along a single transect. Units for nutrients are kg/ha. T = trace.

Vegetation Type	pH	P	K	Ca	Mg
Ridge Sandhills	4.5-5.6	2.3-14.6	6.8-36.0	94.5-236.3	9.0-99.0
turkey oak phase (H)	5.4	2.3	23.6	94.5	9.0
hickory phase (H)	5.6	3.4	36.0	236.3	99.0
hickory phase (V)	4.5	14.6	6.8	113.6	27.0
Sand Pine Scrub	4.2-5.2	T-3.4	5.6-29.3	113.6-212.6	27.0-32.6
oak phase (H)	5.2	3.4	29.3	212.6	32.6
rosemary phase (V)	4.2	T	5.6	113.6	27.0
Scrubby Flatwoods	4.1-4.8	2.3-9.0	4.5-40.5	126.0-283.5	28.1-78.8
inopina phase (H)	4.8	9.0	40.5	252.0	78.8
inopina phase (V)	4.1	2.3	4.5	126.0	28.1
live oak phase (H)	4.8	5.6	31.5	283.5	37.1
Flatwoods	3.5-5.0	2.3-18.0	10.1-72.0	101.3-1058.6	30.4-288.0
palmetto phase (H)	4.9	18.0	72.0	1058.6	288.0
gallberry phase (H)	4.4	4.5	63.0	206.1	127.1
gallberry phase (V)	3.5	3.4	28.1	119.3	156.4
wiregrass phase (V)	4.2	2.3	10.1	113.6	37.1
cutthroat phase (H)	4.6	7.9	41.6	157.5	55.1
cutthroat phase (V)	5.0	5.6	21.4	101.3	30.4
Swale (V)	3.7	2.3	13.5	119.3	60.8
Bayhead (H)	4.7	2.3	57.4	47.3	64.1
Seasonal Ponds	3.9-4.9	T-9.0	4.5-47.3	12.4-532.1	14.6-75.4
broomsedge (H)	4.8	6.8	37.1	252.0	59.6
cutthroat (H)	4.6	2.3	47.3	94.5	37.1
hypericum (V)	4.7	T	4.5	82.1	14.6
maidencane-wet (H)	4.9	5.6	23.6	532.1	51.8
maidencane (V)	3.9	9.0	21.4	12.4	75.4

have been similar to that of the present for approximately the past 4700 yr. Watts (1975, 1980) analyzed sediment cores collected from Lake Annie, a solution lake on the north boundary of the study area (and recently acquired by ABS), and from these he distinguished 3 vegetation phases for the area surrounding the lake: 1) from about 37,000 to 13,000 BP rosemary pollen makes up 15-20% of the total, along with high percentages for its associated species, *Selaginella arenicola* (spores) and *Polygonella fimbriata*; percentages of oak and pine pollen were lower than at present, while that of grasses and composites (*Ambrosia*) were considerably higher; 2) from 13,000 to 4700 BP rosemary pollen declines to its present level of less than 5% of the total; grass pollen remains high, and pine and oak pollen fluctuate asynchronously; 3) from 4700 BP on pine pollen increases dramatically and presently comprises approximately 60% of the profile, oak pollen declines slightly, and that of grasses and composites drops to low values; pollen of wetland species now bordering the lake (*Ilex*, *Myrica*, *Gordonia*, *Serenoa*) appears at this time, along with that of *Taxodium*, a species not now present in the immediate vicinity. From this record Watts concludes that the climate in the study area has become less arid, as a savannah-like vegetation not represented in Florida today together with xeric types now present only on the driest ridges gave way to modern types circa 5000 BP.

Relation of Fire to Vegetation Patterns: Fire and absence of fire have played major roles in shaping and maintaining the present vegetation associations of ABS. South Florida has one of the highest frequencies of lightning strikes of any region in the United States, with the peak number during the summer rainy season. Lightning strikes on the study area have been casually recorded by J.N. Layne and C.E. Winegarner since 1967 and have been tabulated by Abrahamson (1981) for the period 1967-1980. Some 84% of a total 56 recorded lightning strikes (with and without fire), and some 97% of all recorded lightning-caused fires occurred in the period May through September. The ABS data show a peak of lightning activity during July. These data indicate that natural fires are most frequent during the summer rainy season, although artificial burning has traditionally been done during the winter dry season. National Oceanic and Atmospheric Administration data suggest a probable mean of 10-12 cloud to ground lightning flashes/km^2/yr for Highlands County with approximately 70-80 thunderstorm days/yr (M.W. Maier, pers. comm.). Given an area of approximately 15.4 km^2, we estimate approximately 150-185 lightning strikes/yr within the ABS boundaries. A small percentage of these strikes results in fire, as only 30 lightning strikes out of an estimated 2100-2600 strikes were known to have caused fires during the 14 yrs.

On the study site there is a distinct difference in the fire history of the eastern portion of about 400 ha, including Red Hill, which has not burned extensively since the late 1920s (probably 1927), and the western intraridge valley portion of approximately 1100 ha which has had multiple fires, including natural, accidental, and prescribed, during the 14-yrs (1967-1980). Fires have been suppressed in the eastern portion of the study area since the late 1920s. A total of 817 ha burned in 34 fires during this period, with some areas burning repeatedly (in one case twice within 22 months) and others not at all.

Fire produces a complex pattern of unburned and lightly to severely burned areas as it travels through the mosaic of vegetation associations. The associations vary considerably in flammability, which appears related to the amount of grasses, palmetto, pine duff, and litter. Observations suggest the ridge associations rank in approximate order of flammability from highest to lowest as: swale > flatwoods > ponds > scrubby flatwoods >southern ridge sandhill >scrub > bayhead. It should be emphasized, however, that scrub and bayhead do burn intensely if sufficiently high temperatures and winds are reached in the former case or if sufficiently dry conditions occur in the latter case.

Abrahamson (1984a, 1984b) has pointed out that associations dominated by species that are killed by fire and regenerate by seeding (e.g., sand pine scrub) burn less frequently than associations whose dominants regenerate following fire by sprouting or survive fire by resisting (e.g., flatwoods, scrubby flatwoods).

Our observations from prescribed burns and aging of rosemary shrubs support the suggestion that scrub burns infrequently, but usually burns intensely once ignited (Harper, 1921, 1927; Webber, 1935; Davis, 1943; Richardson, 1977). Temperatures up to 482°C have been recorded during rosemary scrub burns at ABS (Abrahamson, unpubl. data). Ages of shrubs in rosemary stands show a pattern of older cohorts in the center and younger cohorts on the edges where fires in adjacent scrubby flatwoods have reached into the associations and died out (Johnson, 1982). Rosemary scrub burns less frequently than do most other ridge associations partly due to the natural fire breaks of bare ground among the shrubs and partly to the relatively nonflammable nature of the foliage of rosemary and other scrub shrubs. Even-aged rosemary stands result from strong seed germination responses following fire, but this species could not persist in areas with a fire cycle less than 10-15 yr because it takes at least that long for rosemary shrubs to reach reproductive maturity (Johnson, 1982).

The only sizeable oak phase sand pine scrub located in the western, intraridge valley portion of ABS has not burned since the late 1930s or early 1940s. Thus, our comments regarding the effects of fire on this community must be limited. Although sand pine readily seed into disturbed areas such as fire lanes and power lines, little regeneration is evident within the association itself. We would predict that, like rosemary scrub, oak phase scrub requires fire to release large seed crops from the semi-serotinous sand pine cones and for germination and seedling establishment. Casual observations of several sites with individual fire- or lightning- killed sand pine indicate a pronounced, but variable lag of several yr in germination. Other aspects of sand pine life history and the relative lack of fuel in younger sand pine scrub associations also suggest low fire frequencies, probably greater than 30 yr.

In the sprouter-dominated scrubby flatwoods, there is also a distinct lack of easily burned vegetation due to low standing crop biomass and patches of bare sand. When fire does occur (with temperatures ranging from 66-482°C), it can kill above ground vegetation, although it usually passes through scrubby flatwoods in a spotty manner leaving a mosaic of lightly to intensely burned and unburned areas. However, burn coverage and intensity in scrubby flatwoods is appreciably increased with the presence of strong winds. Such fires do little to alter the vegetation pattern, because the shrubs readily sprout from their rhizomes (e.g., *Quercus* spp.) or root crowns (e.g., *Persea*, *Garberia*), restoring the community to its preburn composition (Abrahamson, 1984a).

Flatwoods are well-adapted to frequent fires as most of the species in this association rapidly send up new shoots from underground stems or roots after a burn. Many of the species of this association are highly flammable and thus promote fire. Herbaceous species are less common in long unburned wiregrass flatwoods compared with recently burned stands, apparently because the shrubs shade out the light requiring herbs. A conspicuous response to fire of this association is the extensive flowering of wiregrass, cutthroat grass, white topped aster, crow poison, and broomsedge following spring or summer, but not winter, fires. Flatwoods typically burn vigorously and completely (i.e., leaving few unburned patches, although temperatures may vary appreciably within the association). Temperatures as high as 525°C have been recorded in flatwoods burns at ABS (Abrahamson, unpubl. data).

South Florida slash pine is typically the dominant tree in the study area's scrubby flatwoods and flatwoods associations. Individuals of this species demonstrate some resistance to fire, but only within limits. Abrahamson's (1984b) data on south Florida slash pine mortality from a summer head fire and a winter backfire in the intraridge valley portion of ABS show that smaller size classes (6 cm or less dbh) suffered heavy mortality (45 to 90 %), even in the less intense winter backfire. Larger size classes (greater than 26 cm dbh) generally survived the winter back fire, but suffered over 40% mortality in the more severe summer head fire. The limited ability of south Florida slash pine to resist fire may account in part for this tree's present densities in the study area's flatwoods and scrubby flatwoods. Stenberg's 1982 timber cruise of the intraridge valley portion of ABS (ABS files) noted an area of lower pine density than indicated in Little's original census conducted in 1921 and 1922 (ABS files), in contrast to increased densities in other parts of the intraridge valley. Abrahamson's (1981) 14-yr fire map for ABS showed that this area of lower pine counts experienced 2 fires within 10 yr (1967 and 1977), suggesting that fire mortality may in part account for the reduced south Florida slash pine density. However, this area is a relatively well-drained area and it is possible that south Florida slash pines do not come back in a relatively xeric area as well as in moister areas (i.e., around ponds). Site, fire, and seed source availability may each be important factors in determining slash pine densities.

Swales are highly flammable and are prone to changes in species abundance and evenness after fire (Abrahamson, 1984a, 1984b). In a long unburned condition, cutthroat grass forms a dense low canopy which effectively shades out herbs with basal rosette growth habits such as *Carphephorus* and *Polygala*. Thus removal of this grass canopy by fire results in a considerable increase in herbaceous species populations (Abrahamson, 1984a).

The 2 bayheads in the intraridge valley portion of the study site were both leveled by a fire which occurred sometime between 1944 and 1952. By 1957, aerial photographs show return of coverage and increases in height for bayhead species. This indicates rapid recoveries from fire which probably resulted from sprouting. Another wildfire burned the northwest edge of the more easterly of these associations in May 1979, and, again, the vegetation recovered rapidly to approach the preburn situation. During very dry times, however, fire can consume the muck layer of the soil because the organic matter smolders until sufficient rain soaks the muck to extinguish the fire. Muck fires thus destroy the underground organs of bayhead species.

Fires frequently skip ponds, as many are ringed with a bare sand zone that functions as a natural fire break. When ponds do burn, the species sprout back quickly, except under extreme drought conditions. The vigor of fires in seasonal ponds is directly related to the amount of grass cover. *Hypericum edisonianum* does not support fire but the above-ground shoots are easily killed by the heat of the fire.

Abrahamson (1984a, 1984b) pointed out that typically fire in these associations is not a succession initiating disturbance in the Clementsian sense. In the sprouting associations, although the above ground biomass can be removed by fire, it begins to regenerate within days (except under drought conditions), restoring the community to near its preburn condition within 1-4 years. The postfire association is thus composed of virtually the same genotypes as the preburn association.

In seeding associations, such as rosemary scrubs, there is a major turnover of individual genotypes as the dominants (sand pine and/or rosemary) are killed by fire. But even here the community is not invaded by a set of pioneer species which later give way to an association similar to that killed by fire. Fire results primarily in a genetic turnover, not a species turnover.

Humans, including aboriginal peoples, have undoubtedly influenced fire patterns in the southern Lake Wales Ridge in many ways. During the past half century, the effect has been that of both direct and indirect fire suppression. During the 1930s, intensive efforts were made to extinguish all wildfires, regardless of location or source. At the same time, development activities resulted in establishment of agricultural areas, roads, and housing complexes which functioned as unintentional, albeit effective, fire breaks. More recent cultural features such as power lines and towers may even alter lightning behavior, hence changing the incidence of natural fires (M.W. Maier, pers. comm.). In addition, fence laws enacted in the early 1950s abolished the open range and eventually put an end to the widespread, uncontrolled burning which accompanied it. The overall result is the present situation where, although fires may be ignited more frequently than during the period prior to the mid 1930s, the total area burned on noncommercial land over a given period of time decreases. Under these conditions, questions regarding vegetation development must address the effects of fire suppression or at least reduced fire frequencies on plant communities which appear to have evolved with fire as a natural, somewhat predictable environmental factor.

The eastern portion of ABS represents an extreme case of this phenomenon, with the last fire occurring in the late 1920s. However, fire frequencies in the intraridge valley portion of the study area, which has supported multiple fires, have probably been reduced during the past half century.

Evidence from old photographs (circa 1930) and tree age structure (R.L. Myers, per. comm.) indicates that major changes have resulted from fire suppression on the eastern (Red Hill) portion of the station property. The southern ridge sandhill on the summit of Red Hill has changed from an open understory of wiregrass and turkey oak pictured in circa 1930 photographs to a dense understory of scrub hickory and evergreen oaks with much-reduced wiregrass at present. Descriptions of the southern section boundary of this association in surveyors notes made by Kimmell in 1917 record yellow pine timber with a palmetto understory, which also indicates a more open and less scrubby understory. Sand pines are invading the sandhill association, as shown by their recruitment in the ecotone between sand pine scrub and sandhill, as well as in sandhill. This is in contrast to the scarcity of younger sand pine in the scrub association itself.

In northern Florida, sandhill associations will succeed to hardwoods if fire is excluded (Edmisten, 1963; Beckwith, 1967). It could be argued that this would be the case at ABS, except for a lack of a suitable seed source of hammock species such as *Quercus virginiana* (the nearest being Highlands Hammock State Park, 48 km distant). On the other hand, it is possible that differences in climate (Greller, 1980) and/or substrate (Henderson, 1939) between north Florida and the southern Lake Wales Ridge would prevent sandhills from ever succeeding to hardwoods in the latter region.

Permanent plots in 5 associations (sand pine scrub, turkey oak southern ridge sandhill, inopina scrubby flatwoods, flatwoods, and bayhead) on the unburned hill portion of the study area were sampled in 1969 and resampled in 1979 (Givens et al., 1984). Changes over this short period were primarily structural with thinning of herb and shrub layers and an increase in tree height and canopy coverage. Analysis using Horn's Index of Community Similarity showed little change in species composition or relative abundances.

Comparison of aerial photographs from 1940 to 1981 and examination of surveyors' notes and plats (Jackson, 1859; Childs, 1870; Kimmell, 1917) and timber cruise reports (Little, 1921, 1922, ABS files) for the study area indicate that well-drained sites, especially rosemary scrubs, have remained fairly stable, while some poorly-drained flatwoods areas apparently have succeeded to bayheads (Peroni, 1983). Fire suppression may have facilitated the establishment of south Florida slash pine in seasonal ponds, although Peroni (1983) and Abrahamson's (unpubl. data) observations indicate that lower water tables were often responsible for such invasions, even in ponds of the more frequently burned intraridge valley portion of ABS.

Disturbance: Natural disturbances besides fire affecting the associations studied include hurricanes, tornadoes, and severe freezes. The effects of these climatic occurrences include tree throw in the case of hurricanes and tornadoes, especially of the shallow rooted sand pines, and frost kill or pruning of cold sensitive species such as hog plum (*Ximenia americana*) in the case of extreme cold fronts. These impacts tend to be localized or short lived.

Historical and current anthropogenic impacts on vegetation of the study area aside from alterations of fire patterns include turpentining; logging; grazing; stump removal; establishment of roads, fire lanes, and fire lines; and interconnection of some seasonal ponds with shallow ditches. With the exception of fire lane and road construction, most of these practices were confined to the intraridge valley portion of the study site and took place prior to the parcel's purchase by ABS in 1973. The hill property was carefully groomed with the addition of paths, some plantings, and drainage ditches after its purchase by John Roebling in 1929.

Slash pine and some longleaf pine in the intraridge valley section of the study site were turpentined during the late 1920s through 1934, after which the area was clear cut. This intense logging appears to have had little long-term impact on the vegetation associations involved. Comparisons of 1944 and 1981 aerial photography document appreciable slash pine regeneration, especially in flatwoods margins of seasonal ponds. Comparisons of timber cruise reports made by Little in 1921 and 1922 (ABS files), prior to turpentining and logging activities, with data from a similar census conducted by J. Stenberg in 1982 (ABS files) quantify this trend. This comparison indicates large increases in numbers of slash pine measuring 20 cm or greater in diameter, with 1982 figures exceeding 1921 and 1922 ones by 357%. Exclusion of these stands from harvesting and limited, but not total, fire protection for over half a century probably account for this increased second growth.

Although logging left little impact on vegetation associations in the intraridge valley portion of the study site, plant communities found elsewhere may be more sensitive to such disturbances. The study area's turkey oak sandhill escaped intensive logging and differs markedly from such associations located elsewhere on southern Lake Wales Ridge (Peroni, 1983). The ABS turkey oak sandhill has a fairly dense slash pine canopy, while sandhills off the station possess poorly developed, scattered pine canopies. Turkey oak, scrub hickory, and scrub oaks, especially sand live oak and myrtle oak, in these associations are considerably taller and larger than those of the corresponding association in the study area. Timber cruise reports made by Little in 1921 and 1922 (ABS files) for these sandhills indicate that they were surely logged, but more frequent fires may also account, in part, for the differences observed.

The intraridge portion of the study area was used as natural range, but grazing was never intensive. A small area planted with bahia grass represents the only detectable impact. Likewise connection of several seasonal ponds with shallow ditches to speed internal drainage caused no appreciable changes in these associations.

Activities which disturb the soil, especially bulldozing of roads and fire lanes, or alter water patterns (for example the establishment of drainage facilities) tend to leave lasting scars. The elimination of sprouting species through destruction of root and underground stem systems, and changes in water and light patterns accompanying such activities may allow invasion by various non native vegetation. Most exotic or weedy plants found in the study site occurs along roads, in fire lanes, or in drainage ditches. Roads, fire lanes, and drainage ditches also maintain populations of forbs that are characteristic of open sites (periodically burned areas) and would otherwise be eliminated by canopy closure. These forbs include species in the genera *Lupinus*, *Lechea*, *Stipulicida*, *Euphorbia*, *Cleome*, *Chapmannia*, *Polygala*, *Balduina*, *Dicerandra*, *Asclepias*, and *Paronychia*.

The major conclusion emerging from consideration of the historical natural and anthropogenic influences on the vegetation associations of the study area is that these associations are relatively stable, as indicated by a relative lack of change in species composition.

Geographical Extent of Vegetation Types at Archbold Biological Station: ABS is at the southern limit of sandhill vegetation (Davis, 1967; Henderson, 1939). Pine lands to the south usually occur on limestone soils and have a completely different understory of tropical shrubs. Several authors have remarked that sandhill vegetation in Highlands County is atypical (Harper, 1927; Davis, 1943; Laessle, 1967) in that it is dominated by south Florida slash pine rather than longleaf pine and has a higher cover of evergreen oaks (*Quercus myrtifolia*, *Q. geminata*, *Q. chapmanii*) and a lower cover of wiregrass in the understory than is typical elsewhere in the southeastern United States. The stunted nature of the turkey oak is also a distinguishing feature of this association at the southern limit of its range. The transition from longleaf pine to slash pine occurs south of Desoto City (Harper, 1927). In the northern portion of the range of sandhill vegetation, from north-central Florida to North Carolina and Louisiana, several species of deciduous oaks (*Q. incana*, *Q. margaretta*, and *Q. marilandica*) are added to the characteristic turkey oak in the understory, while the cover of evergreen oaks diminishes (Laessle, 1958; Wells and Shunk, 1931). It is because of these differences that we have chosen to distinguish the sandhills of the study area as southern ridge sandhills.

Sand pine scrub, a vegetation type nearly endemic to Florida, occurs on excessively well-drained white sand soils on recent dunes as well as on former shoreline features (Laessle, 1967). The largest areas of it are found in Ocala National Forest, Marion County, and in Highlands County. The association also occurs or formerly occurred along the Atlantic and Gulf coasts, originally reaching as far south as Marco Island in Collier County and Fort Lauderdale in Broward County (Davis, 1967).

Throughout its range, scrub is characterized by the sand pine, Florida rosemary, and the 3 evergreen oaks, *Q. geminata*, *Q. myrtifolia*, and *Q. chapmanii*. However, as Harper (1921) noted, in southern Highlands County the "sand pine is often wanting or nearly so" in contrast to the dense stands found in Ocala National Forest or along the coast. On these unshaded tracts rosemary may form extensive pure stands, accompanied by the endemic *Quercus inopina*. This species is similar to *Q. myrtifolia* but has larger, tougher, elliptical (vs obovate) leaves and blooms later in the spring than does the latter (Johnson and Abrahamson, 1982). Where the 2 species are sympatric, *Q. inopina* occupies the open, unshaded habitats and *Q. myrtifolia* the shaded understory. A further indication of the distinctiveness of the Lake Wales Ridge scrubs is the presence of 20 endemic plant species.

Scrubby flatwoods have not been distinguished as a separate vegetation type by most authors (e.g. Harshberger, 1914; Harper, 1927; Davis, 1943; Harlow, 1959), but rather lumped with one or the other of the 2 types with which it is transitional (i.e., scrub or flatwoods). Its range is mainly coextensive with that of scrub. Laessle (1942) described it on the Welaka Preserve in Putnam County, and Richardson (1977) described it in Palm Beach County. It also occurs extensively in the Cedar Key area, Levy County, Glades County, and elsewhere (J.N. Layne, pers. obs.). As in the case with some scrub sites, stands of scrubby flatwoods on the southern Lake Wales Ridge are distinguished from those in other parts of the state by the presence of the endemic *Q. inopina*.

Flatwoods is the most extensive vegetation type in Florida (Davis, 1967). The dominant species of pine differs from place to place. At the southern end of the Lake Wales Ridge, south Florida slash pine is more prevalent in flatwoods on the ridge, while longleaf pine is more common off the ridge. To the north, south Florida slash pine is replaced by one or a mixture of 3 other pine taxa: longleaf pine, pond pine (*Pinus serotina*), or typical slash pine (*P. elliottii* var. *elliottii*).

Throughout Florida, bayheads are dominated by 3 species of "bays", loblolly bay, red bay, and sweet or white bay. In peninsular Florida the dahoon holly is also prominent in the understory, whereas in the panhandle deciduous species dominate (e.g., *Cliftonia monophylla*, *Cyrilla parviflora*, *C. racemiflora*, *Itea virginiana;* Carr, 1940). Bayheads of the Everglades region are more elevated than surrounding marshes, whereas Lake Wales Ridge bayheads are present on areas lower than the surrounding flatwoods associations. However, both are probably at the same relative level with regard to water tables.

Although seasonal ponds are a characteristic feature of landscapes throughout Florida, they occupy too small an area to be included in general descriptions or maps of Florida vegetation (Harper, 1927; Davis 1967). Two

TABLE 13. Plants endemic or near endemic (sand pine) to Florida recorded at the Archbold Biological Station.

	Vegetation Type				
Species	Sandhill	Scrub	Scrubby Flatwoods	Flatwoods	Ponds
Andropogon cabansii	X				
Carya floridana	X				
Dicerandra frutescens	X				
Lupinus cumulicola	X				
Eryngium cuneifolium		X			
Hypericum cumulicola		X			
Liatris ohlingerae		X			
Lechea cernua		X			
Paronychia chartacea		X			
Polygonella myriophylla		X			
Asclepias feayi			X		
Trichostemma suffrutescens			X		
Polygala rugellii				X	
Hypericum edisonianum					X
Sabatia grandiflora					X
Andropogon floridanus	X	X			
Rhynchosia lewtonii	X	X			
Eriogonum floridanum	X	X			
Chapmannia floridana	X	X	X		
Palafoxia feayi	X	X	X		
Persea humilis	X	X	X		
Pinus clausa	X	X	X		
Polygonella fimbriata var *robusta*	X	X	X		
Sabal etonia	X	X	X		
Stachys floridana	X	X	X		
Nolina brittoniana	X	X	X		
Pinus elliottii var *densa*	X	X	X	X	
Asclepias curtissii		X	X		
Asimina obovata		X	X		
Garberia heterophylla		X	X		
Helianthemum nashii		X	X		
Ilex arenicola		X	X		
Quercus inopina		X	X		
Satureja ashei		X	X		
Euphorbia polyphylla		X	X		
Centrosema floridanum		X	X	X	
Cuthbertia ornata		X	X	X	
Warea carteri		X	X	X	
Asimina reticulata			X	X	
Petalostemon feayi			X	X	
Satureja rigida			X	X	
Sisrynchium xerophyllum			X	X	
Panicum abscissum				X	X
Total = 43	16(37%)	29(67%)	26(60%)	10(23%)	3(7%)

of the dominants, *Panicum hemitomon* and *Andropogon brachystachys*, have been described as occupying zones similar to those they occupy at ABS, at Welaka (Laessle, 1942), and in the coastal flatwoods of the Appalachicola region (Hubbell et al., 1956). However, the ponds at ABS are distinctive in that 2 of the dominants, *Hypericum edisonianum* and *Panicum abscissum*, are primarily found on the Lake Wales Ridge or adjacent areas and on the sea terrace area a few miles to the southwest of it.

Endemism: Florida has about 385 endemic plant species out of a total flora of ca 3000 species (Long, 1974). The central Lake region, of which ABS is a part, has the highest concentration of these, with 189 species (James, 1961). Explanations offered for this concentration are (1) the isolation of the area as an island or islands in Tertiary and Pleistocene times and (2) a combination of climate and substrate unique to the region (Carr, 1940; Harper, 1949; Neill, 1957; James, 1961; Long, 1974).

At ABS, 43 species (9%) out of a total flora of 470 species (Vander Kloet, 1979) are endemic to Florida (Table 13). Of these, 29 (67%) occur in scrub, 26 (60%) in scrubby flatwoods, 16 (37%) in southern ridge sandhills, 10 (23%) in flatwoods, and 3 (7%) in seasonal ponds.

Nine of the 43 Florida endemics at ABS are more narrowly confined to the Lake Wales Ridge. The majority (7) of these consists of xeric species (scrub, scrubby flatwoods, southern ridge sandhills), including *Hypericum cumulicola*, *Liatris ohlingerae*, *Satureja asheii*, *Paronychia chartacea*, *Dicerandra frutescens*, *Lupinus cumulicola*, and *Warea carteri*; 2 dominate in the seasonal ponds, *Hypericum edisonianum* and *Panicum abscissum*, both of which are narrowly endemic to the southern end of the ridge in Highlands County and adjacent sea terraces. Three additional scrub species restricted to the southern end of the Lake Wales Ridge, which occur near or adjacent to, but not on, the study area proper, are scrub plum (*Prunus geniculata*), pygmy fringe tree (*Chionanthus pygmaea*), and the mint (*Conradina brevifolia*).

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A NEW METHOD FOR IMPROVED FIXATION OF THE CHICK'S INNER EAR

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Abstract: *Our method for fixation of the chick's inner ear involves puncturing the soft temporal bone with a needle and directly flushing the membranous labyrinth with cold glutaraldehyde. The temporal bone is trimmed and immersed in the same cold, aerated fixative. This improved method eliminates the need to perfuse through the oval window and preserves better than vascular perfusion. The method is easy to perform and with practice can be completed in 45-60 sec.*

In recent years, the chick has become an important animal model for inner ear research (Cohen and Fermin, 1978; Hirokawa, 1978; Takasaka and Smith, 1971; Tanaka and Smith, 1978). In investigations of avian ototoxicity (Fermin and Cohen, 1982; Fermin et al. 1980; Park and Cohen, 1982; Park et al., 1982), we placed special emphasis on achieving optimal cellular preservation. We empirically determined the optimal fixative composition and thereby eliminated the possibility of confusing fixation artifacts with drug damage. However, a second problem remained. The avian inner ear, along with its mammalian counterpart, is encapsulated by the temporal bone. The temporal bone prevents the fixative from reaching the inner ear embedded within it. Thus, the temporal bone must be quickly opened to flush the inner ear with fixative before the onset of degradative changes. We outline our method for ensuring rapid penetration of the fixative. By using this method, we have quickly and reliably preserved the various cell types of the chick's inner ear.

Materials and Methods—White Leghorn chicks between 6 and 30 da old were used. They were obtained from Mussel-White Hatchery, Maitland, Florida. The inner ears were fixed in 3.5% glutaraldehyde buffered with 0.1 mM cacodylate containing 5 mM Ca^{2+} and 2 mM Mg^{2+}, pH 7.4. Final osmolarity was 560 mOsM. We (Cohen and Fermin, 1978; Park and Cohen, 1982) explained the importance of fixative composition elsewhere. The method involved 5 steps: 1) cutting head in half along the dorsal midline; 2) removal of the brain; 3) injection of the fixative (perfusion); 4) trimming the skull; and 5) immersion and aeration of trimmed tissue. These 5 steps are illustrated with schematic diagrams and explained in more detail below.

First, immediately following decapitation, the head was cut in half along the dorsal midline. Prior to the cut, the razor was centered in the shallow recess on the cranial roof (midline sutures between the frontal bones) and aligned with the comb and beak. Then the razor blade was pressed down

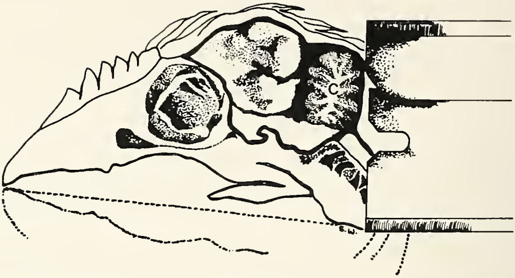

FIG. 1. The divided head. The head was sectioned with a razor blade. The right half is shown from the medial (inner) surface. The cerebellum (C) serves as an important landmark because of its proximity to the inner ear.

firmly in a smooth, continuous movement (Fig. 1). The head was split into equal halves and laid open.

Second, the brain was scooped out with a small spatula to expose the temporal bone (= periotic capsule) that encased the inner ear. As one half of the head was being prepared, the other half was temporarily placed in a beaker of cold (4 C) fixative.

Third, the locations of the semicircular ducts, though not visible through the temporal bone, were accurately estimated by following the outline of the bony canals. The latter were identifiable from the medial side as raised ridges lying directly lateral to the cerebellum. The needle tip (26 gauge) was carefully inserted through the wall of the bony canal and into the perilymphatic region (Fig. 2). The tip was positioned inside the canal but outside the membranous duct, a spatial relationship analogous to inserting a needle between a tire and a partially inflated inner tube. Once the needle tip was positioned within the canal, the cold (4 C) fixative (about 0.25 ml) was slowly injected from the syringe. The immediate outward flow of fixative from below the lagenar region (Figs. 2 and 3) indicated that the syringe was properly positioned within the perilymphatic duct. By comparison, the fixative did not readily flow from the base of the skull when the syringe was improperly inserted (i.e., into a blind sac) despite being forcefully injected from the syringe). The second set of injections delivered fixative (about 0.25 ml) directly above the saccule and utricle. This region is encased by the bony mound. Finally, the fixative (about 0.5 ml) was injected into the bony labryrinthic canal surrounding the lagena (Fig. 3). The lagenar macula (otolithic organ), a vestibular organ located at the tip (distal end) of the lagena, was usually visible through the bone in young chicks. It served as a marker to locate the lagena and guide the accurate insertion of the needles. To avoid puncturing the lagena during this injection, the needle was vertically positioned on either side of the inferred position of the lagena and

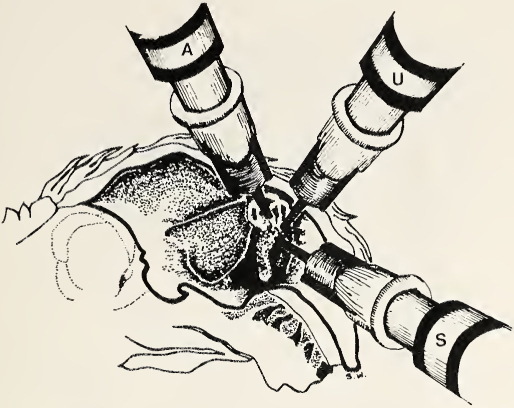

FIG. 2. Injection of fixative in and around the vestibular apparatus. The needle is inserted into 3 sites in temporal bone near the vestibular apparatus: 1) anterior vertical canal (A); 2) utricle (U); and 3) saccule (S). The lagena, which extends from the saccule, points downward. (Each syringe barrel is identified by a letter.)

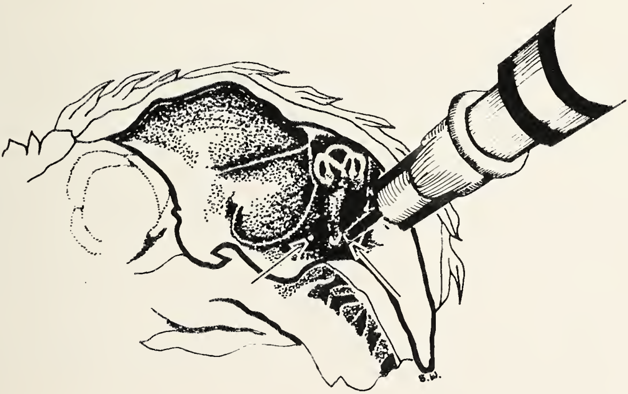

FIG. 3. Injections of fixative around the lagena. The fixative (about 0.25 ml) was injected on each side of the lagena (arrows).

midway between the bony mound and the distal tip. When the lagenar macula (otolithic organ) was not visible, injections were made approximately 2 mm below the lateral edges of the bony mound encasing the utricle and saccule.

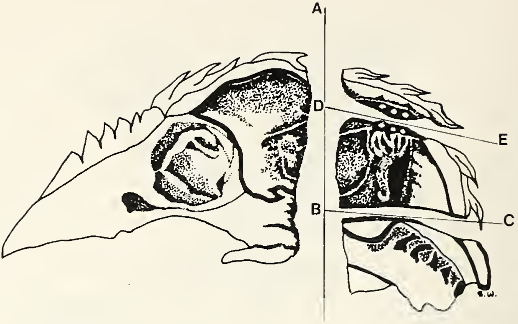

FIG. 4. Trimming procedures. The skull is first cut vertically along the ADB plane and is then cut along horizontal planes BC and DE. Note that cut DE either exposes or lops off the tops of the canals, depending upon the cutting angle.

Fourth, immediately after injection of fixative into both halves of the skull, each half was trimmed to remove extraneous bone. The trimming required 3 major cuts. The first, an oblique cut along line ADB (Fig. 4), removed the eye and the rostral portion of the skull (Fig. 4). The razor blade was angled slightly away from the inner ear to avoid damaging it. The second cut, also oblique along line BC (Fig. 4), removed the basioccipital bone, the ventral portion of the temporal bone, and the neck stump. It was very important when making this second cut to avoid trimming off the distal end of the lagena. To avoid excessive trimming, the ridge of the adjacent cerebellar cavity was located and followed dorsoventrally until it curved caudad. The cut was then made just below this portion of the ridge. The third cut (along line DE) across the top of the canals and through the semicircular ducts allows the fixative to penetrate directly into the endolymphatic regions. In addition, the lagena was also split open by a small transverse cut extending halfway through the trimmed specimen the trimmed specimen made with the razor positioned perpendicular to the long axis of the lagena. Then tissues on the external surface (i.e., muscle, skin, and feathers) were trimmed away. The completely trimmed specimen (Fig. 5) contains the intact membranous labyrinth.

Fifth, the specimens were then immersed in cold (4 C), aerated fixative. Following 10 min of aeration by continuously bubbling atmospheric O_2 through the fixative, the immersed specimens were refrigerated at 4 C for about 24 hr before beginning the final isolation of the inner ear from the temporal bone. Because the original injection holes in the temporal bone remained visible indefinitely, they served as landmarks for locating various inner ear regions during isolation.

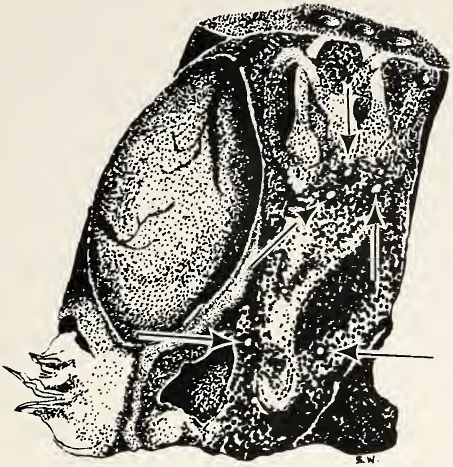

FIG. 5. A trimmed specimen. Note the injection holes (arrows) in and around the inner ear. In this diagram, the tops of 2 canals have been cut off.

DISCUSSION—The mammalian inner ear is embedded in the petrous (stony) temporal bone. The bone is difficult to puncture quickly by routine procedures. By comparison, the avian temporal bone is porous (pneumatized) (Jollie, 1958). Thus, we could puncture the chick's soft temporal bones with the syringe needle to perfuse the fixative directly through the perilymphatic spaces. With practice, we routinely perfused and trimmed the specimen in 45-60 sec, which ensured the rapid delivery of the fixative before the onset of degradative changes. After the tissue was fixed, we isolated the membranous labyrinth from the temporal bone. With slight modifications, we employed this method for preserving the inner ears of mice.

Our method is considerably faster than conventional techniques of perfusion through the oval and/or round windows, or intralabyrinthine perefusion (Takasaka and Smith, 1971). Although these methods preserve well (Anniko and Lundquist, 1977), they are slower and more difficult to perform.

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Biological Sciences

STATUS OF THE MOUNTAIN MULLET IN SOUTHERN FLORIDA

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ABSTRACT: *The mountain mullet* (Agonostomus monticola) *is a rare component of the Florida ichthyofauna. Until recently, records for the southern half of the peninsula were nearly nonexistent. We document and summarize the range, size distribution, and habitat occurrence of the mountain mullet in southern Florida. Florida populations are characterized by low numbers of small individuals that are probably recruited from the West Indies via surface ocean currents. Its rarity in southern Florida seems due to the absence of suitable freshwater stream habitats. Mountain mullet persistently occur in southern Florida in an artifically maintained stream with access to salt water. We collected 5 mountain mullet from this population, including the largest documented United States specimen. We also observed additional adult-sized mullet there. Based on current understanding of the life history of* A. monticola, *we discuss the possibility that Parrot Jungle may hold the first breeding population for the United States.*

THE mountain mullet *(Agonostomus monticola)* commonly occurs in high-gradient freshwater streams in the West Indies, Central America, and northern South America (Hildebrand, 1938; Gilbert, 1978). The larvae undergo a period of development in salt water before entering fresh water and have been collected off the east coast of Florida (Anderson, 1957). Postlarval specimens have been collected only occasionally in the southeastern United States, mainly in Florida, Louisiana, and Texas. The northernmost record comes from the coast of North Carolina (Rohde, 1980). Although Carr and Goin (1955) and Briggs (1958) listed the Florida range of the mountain mullet as encompassing the entire state, the mountain mullet is considered to be rare (Gilbert, 1978), and no records existed for the southern half of the peninsula until recently. Previously, the southernmost published records from fresh water in Florida were from creeks in Volusia County on the Atlantic Coast (McLane, 1955) and from Pinellas County on the Gulf Coast (Suttkus, 1956). Recent records of mountain mullet from the Indian River region (Gilmore, 1977) and from Palm Beach County (J. N. Taylor, pers. comm.) have extended the known range southward along the east coast. The apparent lack of records and suitable habitat around the southern tip of the peninsula led Kushlan and Lodge (1974) to omit *A. monticola* from their list of southern Florida freshwater fishes. The mountain mullet has since been collected on several occasions in extreme southern Florida, once in a mangrove habitat in southern Everglades National Park by Tabb et al. (1974), in Black Creek (C-1) Canal (R. Metzer, pers. comm.), and twice from Miami by us. We describe the latter records, review the status of *A. monticola* in southern Florida, and discuss reasons for its scarcity there.

METHODS—We obtained data on mountain mullet through a series of observations beginning in 1977, and from collections made in 1981 and 1982. Observations made from trails that border the stream and pools were facilitated by clear, shallow waters. We collected specimens with a 30-m long seine (5.0-12.7 mm square mesh) and a backpack electrofishing unit that delivered 1.5 amps. We measured salinities at the times of collection with an optical refractometer. The fish were preserved in 10% formalin and later transferred to 70% ethanol. We measured the standard length of each specimen to 0.5 mm, used a dial caliper for all proportional measurements, and made fin and scale counts with a dissecting microscope. We also examined the stomach contents and gonads of the 1982 specimens. All fish have been deposited in the Florida State Museum, Gainesville, Florida.

To evaluate our collections, we corresponded with 15 researchers and curators from institutions suspected to house U.S. collections of mountain mullet. We asked for a listing of the numbers and lengths of U. S. specimens at each institution and also requested available information on the salinity and habitat of the collection locales. All of the information requests were answered.

RESULTS—We found mountain mullet at Parrot Jungle, a Miami tourist attraction, in an artificial stream and pool system fed by pumped ground water. This system empties into brackish water in Snapper Creek Canal (C-2). The artifically controlled head pressure of the stream seems to prevent saltwater intrustion from Snapper Creek Canal and preserves the freshwater character of the stream throughout the year. The only potential barrier to movement into the stream from saltwater via the canal is a large-mesh (2-3 cm square) culvert screen that permits passage of small fishes. Submerged aquatic vegetation in the stream is sparse because of shading by the dense tree canopy.

We had observed small mountain mullet in this stream several times from 1977 through 1980. On 23 January 1981, we observed 3 *A. monticola*, none of which appeared to exceed 80 mm TL. The fish initially eluded capture by taking cover in overhanging marginal vegetation, but we finally captured a single specimen which was photographed and preserved. The standard length was 63.0 mm, the fork length was 75.0 mm, and the weight was 6.09 g.

From 1977 to 1981, we never saw more than 5 mullet on any occasion in the stream. On 30 May 1982, we found that the numbers of mountain mullet had greatly increased. Three or 4 dozen fish were present, including 6 to 10 adults that were estimated to be from 150 to 250 mm in length. Most fish were juveniles or subadults that were swimming in groups in a large pool with moderate current. The fish often surfaced for sunflower seeds thrown into the water by visitors.

On 23 June 1982, we seined 4 specimens that ranged from 26.4 mm to 150.0 mm SL. Four larger specimens escaped by leaping over the leading edge of the seine. Dentition, meristic and morphometric measurements, and buccal characteristics of the specimens were compared with data reported by McLane (1955) and Anderson (1957). The measurements of the four 1982 specimens are in Table 1. All specimens had ctenoid scales, conical teeth, and no teeth on the lips. The premaxillary and maxillary bones extended below the posterior margin of the preorbital in all specimens, and the preorbital bones were wide with a distinctly serrated posterior margin. The dorsal fin count (IV, I-8), anal fin count (II,10), pectoral fin count (i,14 or i,15) and lateral scale count (39-41) of 4 of the specimens were identical to counts reported for other populations (McLane 1955; Gilbert 1978), but the fifth specimen had an anal fin count of II,9. The combination of counts, measurements, and characters clearly establishes the identity of the fish as *Agonostomus monticola*. The identification was confirmed by Carter R. Gilbert (pers. comm.).

TABLE 1. Proportional measurements of four *Agonostomus monticola* from Miami, Florida. All measurements are expressed in thousandths of the standard length.

Standard length (mm)	26.4	64.2	90.0	150.0
Head length	295	286	278	273
Snout length	83	73	71	71
Orbit length	102	84	70	63
Interorbital distance	125	120	98	97
Pectoral fin length	182	190	172	184
Pelvic fin length	159	184	158	171
Anal fin depressed length	227	224	206	201
First dorsal fin depressed length	159	174	154	161
Body greatest depth	265	294	292	270
Body greatest width	128	165	168	173
Caudal peduncle length	155	171	140	186
Caudal peduncle least depth	117	123	116	108
Dorsal fin origin to tip of snout	500	504	493	484
Anal fin origin to caudal base	227	319	294	311

Cohabiting fishes at the times of sampling included: *Amia calva*, *Lepisosteus platyrhincus*, *Anguilla rostrata*, *Notemigonus crysoleucas*, *Gambusia affinis*, *G. rhizophorae*, *Poecilia latipinna*, *Lepomis gulosus*, *L. macrochirus*, *Micropterus salmoides*, *Cichlasoma bimaculatum*, *Tilapia mariae*, *Dormitator maculatus*, and *Gobiomorus dormitor*. The crustaceans, *Callinectes sapidus* and *Macrobrachium acanthurus*, also occurred in the stream. All of the above species are also present in the adjacent Snapper Creek Canal system (Loftus and Kushlan, in press). We believe that the juvenile *Agonostomus monticola* entered the Parrot Jungle system naturally from the Atlantic Ocean via Biscayne Bay and Snapper Creek Canal. The presence of *Anguilla rostrata*, *Gobiomorus dormitor*, *Dormitator maculatus*, and *Macrobrachium acanthurus*, all of which enter fresh water as juveniles, supports our belief. Mr. Nat DeLeon, manager of Parrot Jungle, assured us that mountain mullet had never been introduced there.

We examined the stomach contents and reproductive state of the four 1982 specimens. The 150.0-mm-SL fish was a mature male with large, smooth, creamy white testes. Its intestinal tract was 120 mm long, 80% of its standard length, and contained 2 coleopteran larvae, portions of sunflower seed husks, vascular detritus, and a small quantity of algae. The 90.0-mm-SL specimen appeared to be an unripe or immature male. The stomach contained a volvocaceous alga and coenagrionid naiad remains. The 64.0-mm-SL fish was a juvenile. Its stomach contained two dipteran pupae and an ostracod. The internal organs of these 3 fish were surrounded by ample fat deposits. The stomach of the smallest individual (26.4 mm SL) was filled by several dozen palaemonid shrimp larvae.

DISCUSSION—The collections from Parrot Jungle extend the Florida Freshwater range of *A. monticola* well to the south of previously published accounts (Anderson, 1957; Gilbert, 1978) and establish its continued presence in extreme southern Florida. Correspondence with researchers and with museum curators has revealed that approximately 100 freshwater specimens of mountain mullet have been taken in the continental United States, most from Florida, and nearly all represented unpublished records. All but 3 of the specimens were < 100 mm SL. The 3 largest specimens were 102 mm SL and 104 mm SL (McLane 1955), and 116 mm SL (Gilbert 1978). Our 150.0-mm-SL specimen is the largest we know of from the United States. The smallest Parrot Jungle fish, 26.4 mm SL, is the second smallest freshwater record we know of from the United States, and is within the size range at which juveniles first enter fresh water (Anderson, 1957). The smallest U.S. record for mountain mullet in fresh water (24.3 mm SL) was recently taken in Brevard Co., Florida (R. G. Gilmore, pers. comm.).

The preponderance of small specimens in United States collections is puzzling because this species often exceeds 200 mm TL elsewhere in its range (Erdman 1972). To account for the small size of U.S. specimens, Gilbert (1978) proposed that *A. monticola* either does not live very long in the northern portion of its range or grows slowly because it does not feed to maximum capacity there throughout the year. Erdman (1972) has presented evidence that *A. monticola* is a slow-growing species even in tropical areas. Gilbert's (1978) explanations for the small size of U.S. specimens suggest that individuals may not survive long enough in northern water to reach sexual maturity and may account for the absence of large specimens in previous collections from the continental U.S. The absence of adults in collections could also be an artifact of collecting (Pezold and Edwards, 1983), considering the well-known difficulty of capturing any specimen of mountain mullet (McLane, 1955; Darnell, 1962). However, because of the number of smaller specimens in collections and the lack of published sight records for adults, we feel that the apparent scarcity of adults in U.S. waters is real.

Throughout its range, the mountain mullet is principally found in lotic, but not necessarily torrential, freshwater habitats (Hildebrand, 1938; Darnell, 1962; Caldwell, 1966; Erdman, 1972). Adults appear to be restricted to fresh water, and juveniles have only rarely been taken outside of fresh water (Erdman, 1972; Pezold and Edwards, 1983). Meek and Hildebrand (1916) collected specimens in brackish water in Panama, but did not report their number or sizes. The vast majority of U.S. specimens have been taken in flowing fresh water, either in natural streams or below dam spillways and canal structures. Only occasionally have fish been collected in lacustrine situations (McLane, 1955; Erdman, pers. comm.). We attribute the paucity of southern Florida records for *A. monticola* to the absence of suitable stream habitat there. Southern Florida has vast areas of freshwater, but the habitats are primarily swamps and marshes, not streams. Nearly all natural rivers and creeks along the southeastern coast of Florida have been channelized, and access to them from the sea has often been blocked by salinity-control structures. Natural rivers along the southwestern coast are low-gradient streams that are subject to wide seasonal fluctuations in salinity. Such conditions may not be suitable for *A. monticola*, based upon its habitat occurrence elsewhere in its range. Despite several fish surveys in rivers along the southwest coast (Odum, 1971; Tabb and Manning, 1961; Loftus and Kushlan, in press), we have found only two other collection records from extreme southern Florida (R. Metzger, pers. comm.; Tabb et al. 1974). We believe that the artificial stream and pool system at Parrot Jungle must approximate the preferred habitat of the mullet better than other available aquatic habitats in southern Florida. The number and size distribution of the Parrot Jungle population indicate that conditions there are favorable for survival and persistence.

In view of Anderson's (1957) collections of juveniles in the Gulf Stream off Florida and the absence of spawning records for *A. monticola* in the United States, we agree with him that recruitment from southern regions, probably Cuba, provides the source for mountain mullet occurring along the Gulf and Atlantic Coasts of North America. Recent studies of currents in the northern Caribbean Sea have shown that passive dispersal from the Antilles to southern Florida via surface currents is likely (Metcalf et al. 1977; Duncan et al. 1977). The directions and speed of the major currents would allow time for larval development (Anderson, 1957) and would deliver the larvae to southern Florida. The apparently short-term, non-breeding populations of *A. monticola* in Florida are probably sustained by a supply of recruits that falls out along the Atlantic Coast and moves into freshwater. That recruitment is available to the Parrot Jungle populations is supported by the collection of juveniles nearby in Biscayne Bay (C. R. Robins, pers. comm.).

The presence of large mountain mullet at Parrot Jungle presents the possibility of this being the first reproducing population for the U.S. Male mountain mullet in Puerto Rico can mature at 83.0 mm SL, although ripe females seem to be considerably larger (Corujo-Flores, 1980; Erdman, pers. comm.). Certainly the sizes of the fish at Parrot Jungle and the gonadal state of the 150.0-mm-SL male show that adults were present.

The method of reproduction of *A. monticola* remains unclear. Several authors have considered it to be catadromous, with the adults moving out of freshwater streams to spawn at sea (Anderson, 1957; Gilbert, 1978). At Tortuguero, Coasta Rica, Gilbert and Kelso (1970) collected only juveniles in the estuaries and found adults only in mountain streams. They concluded that *A. monticola* was catadromous, but they presented the alternative possibility that spawning occurs in fresh water with the eggs being washed out to sea. Support for this latter reproductive mechanism, termed amphidromous (Myers, 1949; McDowall, 1968), is provided by the work of Erdman (1972) and Corujo-Flores (1980). C. R. Robins (pers. comm.) also discounts catadromy for this species, and has observed probable spawning behavior of *A. monticola* in Puerto Rican streams. Limited in-stream spawning movements by adults into the lower reaches of the rivers may occur, but ripe adults have always taken in fresh water (Corujo-Flores 1980). Because only larvae and juveniles have been collected at sea and out-migrations of adults from fresh water have never been reported, it seems most likely to us that spawning occurs in the freshwater streams, followed by passive transport of the eggs or larvae to salt water.

This reproductive tactic is employed by other species that inhabit mountain streams in tropical areas (e.g., prawns, *Macrobrachium* spp., and the Puerto Rican goby, *Sicydium plumieri;* Erdman 1972, 1976). These animals commonly occur with mountain mullet in the upper reaches of mountain streams in Puerto Rico (Loftus, pers. observ.). The spawning period for these species coincides with the wet season when the greater volume and velocity of the rivers carry the eggs or larvae into salt water (Erdman, 1972).

The recent increase in the number of mountain mullet at Parrot Jungle could be due either to increased recruitment from sources outside of Florida, or to indigenous reproduction by the Parrot Jungle fish. The question of whether this population is self-sustaining is presently unanswerable. We do not know if the artificial stream system provides suitable spawning conditions, nor do we know if the larvae could successfully undergo development in local marine habitats. However, because adult-sized fish are present and are presumably capable of reproduction, the possibility exists. Its inability to establish permanent breeding populations elsewhere in the United States points to the ultimate unsuitability, either physical or biological, of most available habitats for this species.

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ESTABLISHMENT OF THE MIDAS CICHLID, *CICHLASOMA CITRINELLUM*, IN FLORIDA

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ABSTRACT: *The Midas cichlid,* Cichlasoma citrinellum, *is a polychromatic fish native to Nicaragua and Costa Rica whose color morphs range from cryptic gray to bright orange. In 1981 an established population of the Midas cichlid was discovered in a south Florida canal that contains 6 other species of established exotic fishes. Preliminary food habit studies indicate Midas cichlids in Florida feed on molluscs and other benthic material. A mean lower lethal temperature of 13° C was determined experimentally indicating range expansion in Florida may be limited to the area south of Tampa (approximately latitude 28°N). This species brings the total number of established exotic fishes in Florida to 16, of which 11 belong to the family Cichlidae.*

THE Midas cichlid, *Cichlasoma citrinellum* (Fig. 1), is a polychromatic fish native to the Atlantic slope of Nicaragua including the Great Lakes basin south to Costa Rica (Miller, 1966). In 1981 an established population of Midas cichlids was discovered in the Black Creek Canal located in southeastern Dade County, Florida. Single specimens of the Midas cichlid were first collected in the Black Creek Canal during July and December 1980 at localities 3 km apart. These were presumed to be releases from aquaria as no other specimens were observed or collected until May 1981 when several hundred Midas cichlids were seen. Adults measuring 146-217 mm SL (standard length) were collected along with 15 mm SL fry in June 1981.

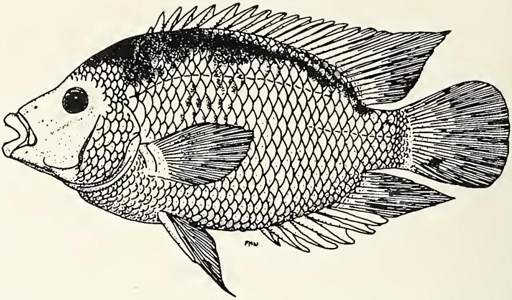

Fig. 1. Midas cichlid, *Cichlasoma citrinellum*, (155 mm SL) collected from the Black Creek Canal in Dade County, Florida.

The range of the Midas cichlid in the Black Creek Canal presently extends from the salinity structure at 87th Avenue westward a distance of approximately 10.5 km. The Black Creek Canal is part of an extensive flood control system and affords the Midas cichlid a route by which to expand its range throughout much of south Florida. A pair of Midas cichlids with fry was sited in June 1982 in the C-102 Canal, located several kilometers southwest of the Black Creek Canal (J. N. Taylor, Florida Atlantic University, pers. comm.).

Methods—Fish were collected by electrofishing and with gillnets. Fish examined for food habits were placed on ice to slow digestion and injected with 10% formalin. Fish were stored in 10% formalin until they were examined in the laboratory where food items were identified using a binocular microscope.

Lower lethal and sublethal temperatures were identified using a 3400 ℓ semi-closed temperature control system per the procedures of Shafland and Pestrak (1982). Eight fish (186-269 mm total length (TL); 139-507 g) were stocked, one per 190 ℓ aquarium and acclimated for 12 da at 27°C. One juvenile (75 mm TL; 8 g) was stocked with 1 of the adults. Temperatures were then decreased 1°C per da in 6 of the aquaria while 2 aquaria were kept at 27°C as controls. The fish were fed a known quantity of Purina® Trout Chow daily.

Food Habits—Stomachs and intestines examined from 16 specimens ranging in size from 154-208 mm SL ($\bar{x} = 175$) yielded the following items and accompanying values (percent frequency of occurrence, percent total volume); pelecypods (94, 53), detritus (63, 10), gastropods (50, 7) and plant material (44, 17). In addition, miscellaneous insects, bryozoans and fish remains were found in 3 or fewer specimens.

Information from studies on Midas cichlids in Nicaragua indicate that it feeds primarily on benthic material, consisting mainly of snails and algae, and feeds by sifting substrate, picking plants or scraping rocks (Barlow, 1976). McKaye (1977) showed Midas cichlids fed on snails, infauna, eggs and algae in the substrate during the dry season and increasingly on adult and larval insects with the onset of the wet season. Lim et al. (1976) state Midas cichlids ingested snails, algae, substrate and an occasional fish, while Barlow (1976) lists algae as the most common food item followed by insects, snails and eggs. Barlow (1976) also reported that Midas cichlids eat young of other fishes, including their own, and suggested they are generally omnivorous but shift to a more piscivorous mode as they approach their maximum size. Young Midas cichlids feed on plankton and aufwuchs, and eat mucus from sides of the parents (Noakes and Barlow, 1973).

Temperature Tolerance—Mean temperatures at which the 7 Midas cichlids, (i) exhibited a marked reduction in feeding was 19.3 °C (sd = 0.95, R = 18-21 °C); (ii) stopped feeding completely was 17.1 °C (sd = 1.07, R = 16-19 °C); (iii) lost equilibrium was 14.1 °C (sd = 0.69, R = 13-15 °C) and (iv) died was 13.0 °C (sd = 0.58, R = 12-14 °C). At temperatures below 15 °C, the isthmus, branchiostegals and edge of the operculum became reddened and distended, and opercular movements appeared laborious.

Lethal temperatures identified in the laboratory were corroborated in a 0.01 ha pond where adult and juvenile Midas cichlids died when overnight water temperatues dropped to 11 °C. Comparison of these lethal temperatures and estimated minimum water temperatures for Florida suggest the Midas cichlid will be limited to an area south of a line connecting Tampa and Melbourne (approximately latitude 28 °N).

Discussion—To date, little information is available on Midas cichlid reproduction in Florida. Midas cichlids were observed guarding fry from May through August and pairs of Midas cichlids were observed guarding what were presumably nests in October, however no fry were observed at this time. Midas cichlids spawned at the laboratory after being placed in outdoor ponds in mid-June, the juveniles measuring 44-60 mm SL in December.

In its native Nicaragua, Midas cichlids usually nest in caves or crevices among rock piles. Less often, pits are dug in more open areas but always adjacent to a hard vertical surface. Eggs are deposited on the walls of caves and crevices or, when pits are constructed, on the vertical surfaces adjacent to the pits. The territory defended by a pair is usually 1 m or less in diameter with 1000-5000 fry being produced (Barlow, 1976).

Polychromatism is known in many fish species, however, differences in behavior and ecology between color morphs have probably been most thoroughly studied in the Midas cichlid (Barlow, 1973, 1976; Webber et al., 1973; McKaye, 1980). The Midas cichlid exhibits 2 basic color morphs. The first of these is what Barlow (1973) called 'normal' and is the most numerous morph in Central American populations. This 'normal' or gray morph consists of a grayish background with markings varying from a series of bars to several large spots along the sides. The second morph consists of an orange coloration which varies from whitish orange to nearly red, often with blotches of black on the dorsal surface. Orange morphs occur nearly equally in both sexes (Barlow, 1976). All Midas cichlid young start out gray, but may later, usually at a total length of 80 mm or larger, undergo a change to gold or orange (G. Barlow, University of California, Berkeley pers. comm.). The smallest orange morphs reported from Central America by Barlow (1976) were 4 specimens ranging from 62 to 66 mm SL. The smallest orange morph we have collected was an 86 mm SL specimen weighing 28 g, while the largest was a 208 mm SL individual weighing 560 g. Orange morphs have been reported to grow faster and to dominate grays in the laboratory (Barlow, 1973).

In Florida 80 to 90% of the Midas cichlids larger than 150 mm SL collected or observed have been the orange morph. The opposite occurs in Nicaragua where 8 to 10% of the adults in some lake populations are orange morphs (Barlow, 1973). Our estimates may be biased toward the more conspicuous orange; however, we are confident the orange morph is currently the most numerous from visual estimates and from collections made with gillnets and by electrofishing.

The establishment of the Midas cichlid brings the total number of exotic fishes known to be established in Florida to 16, of which 11 are cichlids. In the Black Creek Canal, 6 species of exotic fishes are established and include 4 cichlids (*Astronotus ocellatus, Cichlasoma bimaculatum, Tilapia mossambica, T. mariae*), 1 poeciliid (*Belonesox belizanus*) and 1 clariid (*Clarias batrachus*). The source of the Midas cichlid's introduction is unknown but is likely due to release from a local ornamental fish farm. Releases from fish farms have, in the past, been the major source of introduced exotic fishes (Courtenay and Robins, 1973).

The impact of the Midas cichlid on the native freshwater fish fauna is presently unknown. In the Black Creek Canal and adjoining canals, any impact will be on a fish fauna that has already been extensively invaded by exotic species.

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From the Editors:

It would be inappropriate to conclude this volume without recognizing the more than seven years of service that Dr. Walter K. Taylor provided as Editor and Associate Editor. Few can appreciate the many hours of dedicated service that Dr. Taylor provided to the Florida Academy of Sciences and to the authors and readers of *The Florida Scientist*. All of us are indebted to him, and we can only guess at the enormous magnitude of that debt.

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ILLUSTRATIONS—All drawings shall be done in good quality India ink, on good board or drafting paper. Letter by using a lettering guide or equivalent. Typewritten letters on illustrations are unacceptable. Drawings and photographs should be large enough to allow 1/3 to 1/2 reduction in size. Photographs shall be glossy prints of good contrast. Whenever possible, mount photographs in lots size.

The author's name and figure number should be penciled lightly on the back of each figure. Figure legends must be listed on a separate page and *not* on the drawing or photograph. The legend must be double-spaced. Illustrations are charged to authors at $25.00 per page or fraction.

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Florida Scientist

Volume 47 Supplement 1

1984 PROGRAM ISSUE

THE FORTY EIGHTH ANNUAL MEETING OF THE ACADEMY

in conjunction with the
FLORIDA JUNIOR ACADEMY OF SCIENCES
FLORIDA SCIENCE TALENT SEARCH
FLORIDA SECTION, AMERICAN ASSOCIATION OF PHYSICS TEACHERS

Featuring a 1984 Banquet Address:
"FATHOMING THE MYSTERY OF RED TIDES"
By the 1983 Academy Medalist,
DR. KAREN A. STEIDINGER

--A Plenary Address--
"SCIENCE AND THE STATE IN 1984: ONE MAN'S VIEW"
by NATHANIEL REED

And Two Symposia in:
ANTHROPOLOGY: Current Topics in Florida Archaeology
and Historic Preservation;
and
MEDICAL SCIENCE: Acquired Immunodeficiency Disease
Syndrome: "AIDS".

FLORIDA ATLANTIC UNIVERSITY

March 29 - 31, 1984

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES
PROGRAM ISSUE PRICE $2.00

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Florida Academy of Sciences

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FORTY EIGHTH ANNUAL MEETING OF THE FLORIDA ACADEMY OF SCIENCES

At

FLORIDA ATLANTIC UNIVERSITY

BOCA RATON

March 29-31, 1984

Registrants for meetings of the Senior and Junior Academies or the Florida Section, American Association of Physics Teachers are welcome to attend all sessions of all organizations.

Florida Atlantic University

FAU is a state university with upper division and graduate programs. It is located in Boca Raton on the southeast Florida coast. The campus lies on Glades Road between Military Road and U.S. 1. Boca Raton can be reached by Interstate 95 for travelers from north or south Florida, or by Highways 27 or 70 for travelers from the west coast. Commercial air service is available at the Boca Raton Airport, located immediately north of campus.

Registration

All participants are required to register. A Registration Desk will be operated at the GSA (General Classroom South) complex from 8:00 am to 5:00 pm on Friday, March 30, and from 8:00 to 10:00 am on Saturday, March 31.

The registration fee is $8.00 for members, $10.00 for nonmembers and $5.00 for students. Members receive the Florida Scientist Program Issue by mail, as will others registered by March 1. A late registration fee of $2.00 will be assessed for members and nonmembers (students excepted) registering after March 1. Extra programs cost $2.00. Programs will cost $3.50 after April 1, 1984.

Lodging

No reservations can be made through the Academy. The following hotels are a selection of major chains serving the Boca Raton area. Winter rates will still be in effect at the time of the meeting; however, the following hotels will have special rates for Academy members.

Holiday Inn, 2901 North Federal Highway, Boca Raton, FL 33431. (305)395-6850. One and a half miles from the campus. Rates: $60.00 double; $54.00 single bed/day. Contact: Mr. James Coruso.

Hawaiian Inn, 3899 North Federal Highway, Boca Raton, FL 33431. (305)395-7172. One and a half miles from campus. Rates: $43.00 double; $39.00 single bed/day. Contact: Ms. Max Brown.

Howard Johnson's Ocean Resort at Deerfield Beach, 2096 NE Second Street, Deerfield Beach, FL 33441. (305)428-2850. Four miles from the campus. Rates: $65.00/day, double or single. Contact: Ms. Kathy Flagel. This is the convention hotel where the banquet will be held.

University Inn, 2700 North Federal Highway, Boca Raton, FL 33431. (305)395-5225. Three miles from the campus. Rates: $55.00 double; $49.00 single/day. Contact: Mr. John Bruges.

Except where indicated, add about $5.00 per person to the single rate for multiple occupancy. Make reservations as soon as possible and identify yourself as an FAS participant to facilitate communications during the meeting.

Banquet and Food Service

The banquet will be held on Friday evening, March 30. The 1983 Medalist Address by Dr. Steidinger will immediately follow and the 1984 Medalist will be announced. The Banquet will be held at Howard Johnsons Ocean Resort at Deerfield Beach (2096 NE Second Street, 33441), four miles from Florida Atlantic University. Dinner includes appetizer, salad, veal parmesan, vegetable, dessert and beverage; cost will be $12.00 per person including gratuity. Contact Joyce Powers at the Academy office (305-896-7151) to purchase tickets.

The campus cafeteria is adjacent to the meeting rooms and is open from 7:00 am to 1:30 pm on Friday. The Rathskeller is open from noon to mignight. Information about nearby food outlets will be available at the registration desk.

Stand Ins and Cancellations

If the author or a coauthor of a scheduled paper cannot present the paper due to illness, unforseen conflict or other circumstance, the author should arrange for a colleague to read the abstracted paper. If a reader cannot be enlisted, the paper should be cancelled. The Academy should be notified concerning a reader or an intent to cancel. Early notification will allow inclusion of the change in a program supplement and will spare the author of the cancelled paper the embarrassment of an apparent no-show.

Contact (in preferred order) E.D. Estevez, Program Chair (813:388-4441); Joyce Powers at the Academy Office (305:896-7151); the appropriate Section Chair; or the presider of the session.

Field Trips and Tours

The following places are points of interest in the area. Information and travel arrangements will be available at registration.

The Museum of Archaeology, Ft. Lauderdale, FL. Archaeological remains of Native Floridians, about 25 miles from campus (an approximate 2 hour trip including travel time).

Pine Jog Environmental Sciences Center, West Palm Beach. Arrangements are being made through the Department of Biolgical Sciences (approximately 3 hours, including the ride).

Museum of Science and Planetarium, West Palm Beach. The museum includes not only technological and natural science exhibits but also serves as an educational center for students of middle high school age (about 3 hours).

Florida Atlantic University Campus, Boca Raton. The University tour should be of interest. FAU was built on the site of a former U.S. Air Force base and is about 20 years old.

Announcements

Junior Academy Judges

Judges are needed for the Florida Junior Academy of Sciences, which is meeting concurrently with the Science Talent Search and the Senior Academy. If you would like to serve as a volunteer judge during the 1984 meeting, please contact Dorothy Henley, Cardinal Gibbons High School, 4520 NE 15th Terrace, Ft. Lauderdale, FL 33334 (305:772-4836, after 3:00 PM), or the Registration Desk.

Parking

On Friday, March 30 meeting participants should use lots designated for visitor parking. One lot (P-7) east of the General Classroom South is recommended, but others are available. All lots are open on Saturday, March 31.

Handicap Access

All meeting rooms and areas are accessible by ramps or elevators. Every building is provided with passageways and facilities suitable for wheelchairs. Persons with special needs should contact Yasar Iscan, Chairman of Local Arrangements (305:393-3992).

Smoking Policy

Standard policy of the state university system prohibits smoking in all interior spaces.

Special Symposia

Anthropology: "Current topics in Florida Archaeology and Historical Preservation", convened for Friday, March 30 at 9:00 AM in GCS 217 by Dr. J. Raymond Williams.

Medical Sciences: "Acquired Immunodeficiency Disease Syndroms: AIDS", convened for Friday, March 30 at 9:00 AM in GCS 115 by Dr. Caroline MacLeod.

Plenary Session

The Academy Plenary Session will be held on Friday, March 30 in Room 201 of the Administration Building (Number 10 on Campus Map, back cover) at 1:30 PM. Dr. Frank B. Wood, 1983-84 Academy President, will preside. Section chairs should prepare to make their reports at this time.

This year, numerous changes to the Academy Charter and By Laws have been prepared by a Special Council Committee. Members are urged to study the proposed changes and attend the business meeting.

Social Sciences Business Meeting

The section on Social Sciences may meet to conduct business immediately after the Academy Plenary Session in the same room, Administration 201, from 3:00-3:30 PM on Friday, March 30.

Audio-Visual Aids

Carousel slide projectors will be available in each session. Overhead projectors are available on special request to the Local Arrangements Committee or appropriate section chair.

Some meeting rooms utilize common rear screen projection rooms. Every speaker is used to arrive early to determine whether slides must be loaded differently to accommodate the projection system in use.

History of Science in Florida

The fiftieth anniversary of the Academy in 1986 will be highlighted by a special program on the history of sciences in Florida. All Florida scientists and historians with anniversary ideas should look for a special brochure at registration.

Posters and Exhibits

Posters accepted by section chairs can be displayed before and after the appropriate session and during breaks, in the same room or adjacent passageway. Following the Plenary Session on Friday, posters may also be exhibited in GCS 208 until 5:00 PM. Exhibitors are encouraged to bring all necessary materials.

Telephone Services

Yasar Iscan, Local Arrangements -	305:393-3992
Messages to FAS Sessions -	305:393-3230
Campus Police -	305:393-3500

FAS General Council Meeting

There will be a meeting of the council at the Howard Johnsons Ocean Resort, Deerfield Beach, at 7:00 PM on Thursday, March 29. All section chairs and chairs-elect are urged to attend this important meeting. To find the meeting room look for directions in the main lobby.

Acknowledgements

The Program Chair appreciates the technical assistance of Laurie Fraser, Linda Franklin and Bruce Fortune in preparation of the Program Issue.

PLENARY SESSIONS AND BANQUET

PLENARY SESSION I:

Dr. Frank B. Wood, University of Florida, presiding

Friday 1:30 PM, Administration 201.

1:30 PM - Welcoming remarks and announcements

1:35 PM - Plenary Address, "Science and the State in 1984:
One Man's View", by Nathaniel Reed

2:00 PM - Business Meeting

2:50 PM - Introduction of Florida Scientist Editor

BANQUET AND PLENARY SESSION II:

Friday, 6:30 PM - Howard Johnsons Ocean Resort, Deerfield Beach

6:30 PM - Cocktails (cash bar)

7:30 PM - Banquet

8:30 PM - Introduction, Dr. Frank D. Wood

8:35 PM - Fathoming the Mystery of Red Tides; Dr. Karen A. Steidinger,
1983 FAS Medalist, Florida Department of Natural Resources

9:30 PM - Presentation of the 1984 FAS Medal; Dr. George B. Butler,
1982 FAS Medalist, University of Florida

PROGRAM SUMMARY

THURSDAY EVENING, 29 MARCH 1984

7:00 pm	Council Meeting	HJ Ocean Resort*

FRIDAY MORNING, 30 MARCH 1984

8:00 am	Registration (to 4:00 pm)	GCS HALL
8:30 am	Agriculture Sciences A**	GCS 202
	Physics and Space Science**	GCS 208
8:45 am	Environmental Chemistry	GCS 203
9:00 am	Anthropology Symposium	GCS 217
	Geology and Hydrology**	GCS 238
	Medical Symposium***	GCS 115
9:30 am	Biological Sciences A	GCS 204
10:00 am	Environmental Chemistry B**	GCS 203

FRIDAY AFTERNOON, 30 MARCH 1984

1:30 pm	PLENARY SESSION I	ADM 201
3:00 pm	Agricultural Sciences B	GCS 202
	Anthropology A	GCS 217
	Biology B**	FLH 313
	Biology C	FLH 315
	Engineering**	FLH 318
	Environmental Chemistry C	GCS 203
	Medical Science**	GCS 204
	Social Science Business Meeting***	ADM 201

FRIDAY EVENING, 30 MARCH 1984

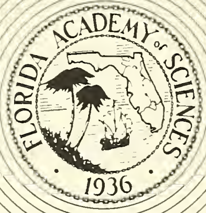
6:30 pm	BANQUET and PLENARY SESSION II	HJ Ocean Resort

SATURDAY MORNING, 31 MARCH 1984

8:00 am	Registration (to 10:00 am)	GCS Hall
8:15 am	Anthropology B	GCS 111
	Computer Science and Mathematics**	GCS 202
8:30 am	Atmospheric and Oceanographic Sciences**	GCS 208
9:00 am	Biology D	GCS 117
	Biology E	GCS 118
	Rare and Endangered Biota**	GCS 204
	Urban and Regional Planning**	GCS 203
	Amer. Assoc. Physics Teachers**	GCS 217
10:00 am	Science Teaching**	GCS 201
11:00 am	Anthropology C**	GCS 111

* Meeting room to be posted in lobby.
** Business Meeting follows.
*** Due to FAU classes the Medical Symposium shall adjourn by 11:00 am and Social Science Business Meeting shall adjourn by 3:30 pm.

ABBREVIATIONS: HJ Ocean Resort, Howard Johnson's Ocean Resort, 2096 N.E. Second Street, Deerfield Beach; GCS, General Classroom Building, South; ADM, Administration Building; FLH, Fleming Hall Classroom Building.


FLORIDA ACADEMY of SCIENCES
1936

AGRICULTURAL SCIENCE

FRIDAY 8:30 am GCS 202
SESSION A: Crop Production; Agricultural Land Use
K.L. BUHR, University of Florida, presiding

8:30 am AGR-1 Motility of Meloidogyne javanica After Exposure to Two Natural Plant Compounds. C. H. OPPERMAN AND E. L. DAVIS, Nematology, IFAS, UF. A variety of natural plant compounds that are known to have adverse effects on invertebrate animals have been screened against various nematode species. This study examined ricin, a lectin produced in seed of castor (Ricinus communis L.), and nicotine, an alkaloid produced in roots of tobacco (Nicotiana tabacum L.). These compounds were screened at selected concentrations against second-stage juveniles (J2) of M. javanica. The 'in vitro' effect of ricin and nicotine on nematode motility was observed. There was no effect on J2 motility observed at even the highest concentration of ricin (100ug/ml). The effective concentration of nicotine which reduced motility by 50% (EC50) was approximately 25ug/ml. Low permeability of the nematode integument to the relatively large ricin molecule may account for this compound's low activity. Nicotine was apparently able to gain entry into the nematode where it may have adversely affected the nervous system.

8:45 am AGR-2 Effects of Winter Crop, Tillage and N Fertilization on Yield and Nutrient Uptake in Grain Sorghum. V.J. EYLANDS AND R.N. GALLAHER, Department of Agronomy, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. When winter legumes are coupled with no-tillage planting of a summer crop, the system may be able to better utilize available soil moisture as well as residual N from the winter legume. Crimson clover (Trifolium incarnatum L.) was seeded in the Fall. Prior to grain sorghum (Sorghum bicolor L.) planting in May, the clover residue was either left standing or was cut for forage. The sorghum was then seeded with either no-tillage or conventional tillage seedbed preparation. Seven N rates (0 to 200 kg N/ha) were imposed on each main plot. Nitrogen concentration in the third leaf below the flag was higher when the clover residue remained, but was unaffected by tillage. Final grain yield and N content of the grain was highest in conventionally tilled plots where clover residue was left, and did not increase above the 75 kg N/ha rate. Whole plant N content was also highest for the same treatments.

9:00 am AGR-3 Growth and Yield Variables of Temperate and Tropical No-Tillage Planted Corn Cultivars in Florida. J.A. BALDWIN AND R.N. GALLAHER, Agronomy Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. Interest has occurred recently in the production of tropical corn (Zea maize L.) as a grain and forage crop in Florida. Growth and yield variables were evaluated utilizing two temperate, one open pollinated, and six tropical corn cultivars. Cultivars were planted in early March 1983 and managed for high yields including irrigation. Temperate hybrids Asgrow RX 114 and DeKalb DK 747 exhibited the highest grain yields with 9977 and 9828 kg/ha, respectively. Whole plant yields were highest for RX 114 (30,432 kg/ha) followed by Pioneer brand 304C a tropical hybrid, (27,283 kg/ha) and DeKalb DK 747 (26,535 kg/ha). Whole plant yields ranged from 18,171 kg/ha for tropical hybrid DeKalb EXA 815 to 30,432 kg/ha for Asgrow RX 114. There were also differences among the nine cultivars for N content in grain, stalks, total plant and for the ratio of N in grain to stalks and in shelling percent, and in the grain/stalk ratio.

9:15 am AGR-4 Minimum Tillage Peanut Management in Florida. S.R.COSTELLO AND R.N. GALLAHER, Agronomy Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. In a three year study comparing minimum tillage peanuts with conventionally tilled peanuts (Arachis hypogaea L.), both with and without a rye (Secale cereale L.) straw mulch, no differences in peanut yields, harvest index, or shelling ratios were found. Minimum tillage peanuts yielded as well as conventionally grown peanuts with a high of 1500 kg/ha versus 1200 kg/ha for minimum tillage and conventional tillage, respectively. There was a trend for increased yields of minimum tillage peanuts when a rye straw mulch was left on the surface. There were fewer broadleaf weeds in the minimum tillage over all three years as compared to conventional tillage. In another one year study, neither rates of rye straw mulch (from zero to 6,000 kg/ha) nor gypsum application resulted in yield differences of minimum tillage peanuts.

9:30 am AGR-5 Organic Matter and Nitrogen in an Ultisol as affected by Cropping and Tillage Systems after Seven Years. RUBEN A. ORTIZ AND R.N. GALLAHER, Agronomy Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. This research was conducted to evaluate soil organic matter (OM) and N at different depths in a seven year oat (Avena sativa)/soybean (Glycine max L. Merr.) versus oat/grain sorghum (Sorghum bicolor L. Moench) multicropping experiment as affected by tillage. Cropping systems were split plots randomized within whole plots of four tillage variables. The whole plots were in a randomized complete block design with four replications and included no-tillage versus conventional tillage with and without in-row subsoiling. Soil samples were taken in 12 increments of depth to 80 cm for laboratory analyses of N and OM. Tillage affceted N and OM only in the top 15 cm. Cropping systems had little effect on these variables. Soil N and OM were very highly positively correlated throughout the soil profile. Both N and OM decreased linearly from the surface (N=0.06% and OM=1.57%) to a depth of 35 cm, (N=0.015% and OM=0.45%), then increased to a depth of 50 cm (N=0.022% and OM=0.71%), then decreased at the 70 cm depth (N=0.011% and OM=0.32%), and increased again at 80 cm.

9:45 am AGR-6 Soil Nitrogen and Organic Matter Changes as Affected by Tillage Following Six Years of Corn. MAGLENE B. FERRER, R.N. GALLAHER, AND B.G. VOLK, Soil Science and Agronomy Departments, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. Chemical changes in soil properties are expected from different tillage systems. Nitrogen and organic matter (OM) were measured to a depth of 60 cm in tillage treatments on an Alfisol in a six year old corn (Zea maize L.) experiment. The experiment was a split plot with conventional and no-tillage treatments as whole plots, and position of sampling either over the row or between the rows as split plots. No-tillage treatments had 45% more N in the top 15 cm of the soil as compared to conventional plots (.065% N in no-tillage versus .045% in conventional). This same relationship was found for organic matter with no-tillage plots having 35% more OM than conventional. There was a close positive correlation between N and OM and they decreased linearly with depth. The decrease from the surface to 60 cm was from about 2.00 % to 0.50% for OM and 0.05% to 0.013% for N.

10:00 am BREAK

10:15 am AGR-7 Maize-Sorghum Farming Systems in Central America. F.R. ARIAS AND R.N. GALLAHER, CATIE Turrialba Costa Rica and the University of Florida, IFAS, 631 Wallace Building, Gainesville, FL 32611. In the semi-arid regions of Central America, farmers have developed a maize (Zea maize L.)-sorghum (Sorghum bicolor L. Moench)/animal system in response to environmental characteristics and needs for food. The objective of this paper is to present a situational analysis of the system in its environment. Management of the system and the structure of its components are based primarily on environmental variations, socio-economic structure, and technological adaptability. There have been few studies of the relationship among components in this system, or in the analysis of inputs and outputs, although it is a commonly found system in poor farms of areas with high demographic pressure (100 to 200 inhabitants/km^2). In the scientists search for alternatives that will help these farmers, an understanding of the system, and an analysis of the alternatives within the farmer's possibilities are necessary.

10:30 am AGR-8 Developmental Differences Among Three Pioneer Corn Hybrids Subjected to Drought Stress. G. F. LORENS AND J. M. BENNETT, Agronomy Dept., IFAS, University of Florida, Gainesville, FL 32611. Corn (Zea mays L.) hybrids are usually developed for ideal conditions of water availability. However, many acres of corn in the U.S. are grown under less than ideal conditions due to natural drought or lack of adequate irrigation. Corn is planted in early spring in northern Florida to avoid summer disease and insect problems and is often subjected to spring droughts. In this study, three corn hybrids (Pioneer 3165, 3040, and 3192) known to differ in their response to drought stress, were subjected to three water management treatments (rainfed, irrigated, vegetative stress). A complete growth analysis was conducted to determine differences in development, dry matter partitioning, and yield. Genotypic differences were observed only during severe stress (rainfed). Variety 3192 wilted sooner, had lower leaf water potentials, and yielded significantly less when severely stressed, but yielded the same as other varieties in the moderately stressed and fully irrigated treatments.

10:45 am AGR-9 Preliminary Evaluation of the Yam Bean Grown in North Florida Sandy Soil. STEVEN C. GILLIS AND K. L. BUHR, Agronomy Dept., IFAS, University of Florida, Gainesville, FL 32611. Two varieties of Yam Bean (Pachyrhizus erosus (L.) 'Agua Dulce' and 'Cristalina') were grown on Arredondo fine sand at Gainesville, Florida in 1983 for preliminary observation and evaluation. Three replications were planted using a randomized complete block design. Rows were spaced 51 cm apart with an intra-row spacing of 30 cm between the plants. The plants were grown without the use of herbicides or fertilizer treatments with only minimal supplemental irrigation. Yields of 43,400 and 36,015 kg/ha were recorded for the varieties 'Agua Dulce' and 'Cristalina,' respectively.

11:00 am AGR-10 Potential for Increasing the Resistance of Cowpeas to Oviposition by the Southern Cowpea Weevil. MICHAEL S. FITZNER, Dept. of Agronomy, UF, Gainesville, D. W. HAGSTRUM, Dept. of Entomology and USDA-ARS, Kansas State Univ., AND D. A. KNAUFT, Dept. of Agronomy, UF, Gainesville 32611. A collection of 36 cowpea (Vigna unguiculata L. Walp.) genotypes was tested to determine the selection differential for pod resistance to oviposition by the Southern Cowpea Weevil (Callosobruchus machulatus F.). The resistance of each genotype was measured with a series of biological assays using pods in three stages of maturity and female C. maculatus at two oviposition propensity levels. Highly significant differences were found in the resistance levels of the cowpea genotypes tested. The reduction in oviposition observed between the most susceptible and the most resistant genotypes ranged from 69.2% on young pods using females with a high propensity to oviposit to 100.0% on mature pods using females with a low propensity to oviposit.

11:15 am AGR-11 Integrated On-Farm Research/Extension: Examples From North Florida. M. E. SWISHER AND E. C. FRENCH, Live Oak ARC, Live Oak, FL and Agronomy Dept., UF, Gainesville, FL 32611. The farming systems approach to research and extension is holistic. Within this methodology, the farmer, extension agent, and researcher are incorporated into a team who can identify problems within the farming system, develop alternative solutions to those problems, and test those solutions under farm conditions. The farm is viewed as a system wherein animal and crop production are integrated functions.

A multi-disciplinary effort tested in Suwannee and Columbia counties, Florida illustrates the use of this methodology. Examples of research and extension programs with a relatively new winter grain crop, wheat, show how research questions have been generated and solutions tested on area farms. Results of wheat grazing trials and K_2O application rate trials are discussed.

11:30 am AGR-12 Development Encroachment on Agricultural Lands, 1972-1980: Planning Region VII. NICHOLAS STASZKO, Central Florida Regional Planning Council, P.O. Box 2089, Bartow 33830. Rapid population growth is creating intense competition for land currently in agricultural production. The greatest competition is for land in citrus production. Polk County alone has lost over 12,000 acres of citrus almost exclusively to development pressure. Of primary concern is the displacement of citrus to less productive soils. The evidence indicates that major citrus expansion is taking place in lowland areas with high water tables where citrus does not thrive naturally. The purpose of this paper is to discuss the possible impacts of producing citrus on these marginal or unsuitable lands.

FRIDAY 11:30 am GCS 202
BUSINESS MEETING: Agricultural Sciences Section
J.M. BENNETT, University of Florida, presiding

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

FRIDAY 3:00 pm GCS 202
SESSION B: Plant Growth and Development; Physiology and Biochemistry
J.M. BENNETT, University of Florida, presiding

3:00 pm AGS-13 Influence of Inoculum Placement and Fertilizer N on Efficacy of *Rhizobium japonicum*. WALTER T. SCUDDER, UF, IFAS-AREC, Box 909, Sanford, FL 32771. Seed treatment was compared with soil-furrow placement of inoculum using soybeans (*Glycine max* (L.) Merr.). The field had not been used previously for soybeans and was mostly free of *R. japonicum*. Fertilizer N (NH_4NO_3) was supplied at 0, 50, 100, 150, and 200 kg N/ha, split into 5 equal increments applied at 2-week intervals. Plant fresh weight, dry weight, height, intensity of green color, N-content, and seed yield all increased with N application rate from 0 to 200 kg/ha. In contrast, nodulation, as measured by nodule fresh and dry weight, decreased progressively with increases in N fertilization. Plant weight, nodulation, and total N content following soil inoculation were more than double those obtained with seed inoculation. Seed inoculation was superior to the 0 inoculation level in the absence of fertilizer N. However, when fertilizer N was added, at all levels from 50 to 200 kg/ha, plant fresh weight, dry weight, and N content were greater without inoculation than when the inoculum was applied on the seed.

3:15 pm AGS-14 Plant Response to Rate of Inoculation with Rhizobium N-fixing Bacteria. WALTER T. SCUDDER, UF, IFAS-AREC, Box 909, Sanford, FL 32771. Several studies have been made to determine the numbers of R. japonicum bacteria required to perform a successful inoculation of soybeans (Glycine max (L.) Merr.). Under field conditions, results have been variable due to the presence of indigenous Rhizobium populations and to various stress factors which decrease the survival and effectivity of the cultured bacteria. Rate of inoculation experiments were conducted on soil free of indigenous R. japonicum. Liquid cultures of USDA strain 110 were distributed in the seed furrow at calculated rates of 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, and 10^9 colony-forming units (CFU) per cm of row. Of two 0-inoculum controls, one received 40 kg/ha of N from NH_4NO_3 at 2-week intervals, beginning at planting and continuing for 5 applications. Under favorable conditions, several plant responses improved with increasing inoculation rate, reaching a plateau at 10^6 CFU. Under less favorable conditions, these parameters, including seed yield, continued to improve as the rate was increased through 10^9 CFU/cm of row.

3:30 pm AGS-15 Comparative Studies of Monoecious and Dioecious Hydrilla Biotypes. K. K. STEWARD AND T. K. VAN, U. S. Department of Agriculture, Aquatic Plants Management Laboratory, 3205 College Avenue, Fort Lauderdale 33314. Wild colonies of a monoecious biotype of Hydrilla verticillata Royle have been reported from the NE U.S. and from NC. The occurrence of these wild colonies greatly increases the potential, through sexual reproduction, for genetic diversification and adaptation to different habitats. Only the dioecious female was previously known in the U.S. Investigations comparing the physiology of these two biotypes are currently in progress. We will report on the following: 1) Flowering and growth response to photoperiod, 2) partitioning of photosynthate between roots, shoots and propagules, 3) fragment survival and regrowth as related to establishment and distribution of colonies, 4) salinity tolerance (to determine how far seaward plants will establish), 5) susceptibility to registered aquatic herbicides.

3:45 pm BREAK

4:00 pm AGS-16 Influence of Pesticide Spray Schedule on Growth and Yields of Cowpeas. R. C. BULLOCK, P. J. STOFFELLA, AND R. M. SONODA, University of Florida, IFAS, Agricultural Research Center, P. O. Box 248, Ft. Pierce, FL 33454. The growth and yield of 4 cowpea (Vigna unguiculata L. Walp) cultivars were evaluated during Fall 1982 and Spring 1983 under 3 pesticides spray regimes: preventative (weekly), on demand, or unsprayed. Major pests encountered during the Fall 1982 trial were: bean leafroller (Urbanus proteus L.), southern green stink bug (Nezara viridula L.), unidentified leafminer, rust (Uromyces phaseoli typica) and powdery mildew (Erysiphe polygoni). In Spring 1983 major pests were leafminer and powdery mildew. Plots sprayed weekly had significantly higher seed and biological yields than plots sprayed on demand or unsprayed. Reduced seed yield of on demand or unsprayed plots were associated with significantly lower numbers of pods/plant, numbers of seeds/plant, and numbers of seeds/pod. Perhaps high threshold levels for certain pests or ineffective chemicals resulted in lower yields in on demand plots compared to preventative spray plots.

4:15 pm AGS-17 Root Morphological Characteristics of Cowpeas. PETER J. STOFFELLA AND BONITA J. WILLIAMS, University of Florida, IFAS, Agricultural Research Center, P. O. Box 248, Ft. Pierce, FL 33454. Total root biomass of seven cowpea (Vigna unguiculata L. Walp) cultivars was partitioned into lateral, basal, and taproot components during anthesis under field conditions. Basal roots, taproots, and lateral roots comprised an average of 44, 19, and 37% of the total dry root weights, respectively. Only taproot dry weight differed among cultivars.

Taproot diameter was correlated to lateral root weight (r=0.86) but not with taproot dry weight (r=0.16). Shoot and root dry weights did not differ among cultivars, however, shoot:root ratio of 'Purple Hull Big Boy' was significantly higher than the other cultivars, except when compared with 'Knuckle Purple Hull'. This suggests that cultivars with smaller shoot:root ratios translocated a greater portion of photosynthates to the roots than to the shoots.

4:30 pm AGS-18 Investigations of Laboratory Errors From the Two-Stage In Vitro Organic Matter Digestion of Plant Tissues. R.N. GALLAHER, Agronomy Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 32611. The "Tilley and Terry" two-stage in vitro digestion technique for plant tissues involves a 48-hour fermentation by rumen microorganisms followed by a hydrochloric acid-pepsin digestion. The amount of organic matter that has disappeared is considered to have been digested. This study evaluated the above procedure to identify processes where laboratory variables could most likely cause serious errors in digestion data. Variables evaluated were different technicians, carbon dioxide saturation of rumen fluid inoculate, pH of artificial saliva, amount of HCl added prior to second stage digestion, sample agitation, incubation temperature, muffle furnaces, desiccators, and how these variables affected a wide range of plant tissues. It was found that most striking errors were caused by incubation temperature being too low, agitation of tissue during incubation, and improper use of pepsin. Least errors were caused by muffle furnaces, and desiccators.

4:45 pm AGS-19 Nitrogen Cycling in a Perennial Peanut Sod. E. C. FRENCH, G. M. PRINE, R. ORTIZ, AND J. HERBAS, Agronomy Dept., IFAS, University of Florida, Gainesville, FL 32611. Perennial peanut (Arachis glabrata Benth.) is a warm-season perennial forage legume with high potential for hay or grazing. Work has been initiated to examine the nitrogen contribution of perennial peanut to various cropping systems. Forage yield of winter rye overseeded into perennial sod was not significantly less than rye harvested in conventionally tilled treatments. Mean yield of the zero nitrogen treatment was approximately 24.6 kg/ha of applied nitrogen. Soil solutions, analyzed for NH_4 and NO_3 taken from perennial peanut sod and tilled plots seeded with corn during the spring and summer seasons, indicated that sod treatments contained approximately 178% more NO_3 at the 30 cm depth and 250% more NO_3 at the 60 cm depth in the soil profile. However, forage and grain yields of corn were significantly lower in the sod treatments.

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences

ANTHROPOLOGICAL SCIENCES

FRIDAY 9:00 am GCS 217
SYMPOSIUM: Current Topics in Florida Archaeology and Historic Preservation
J.R. Williams, University of South Florida, presiding

9:00 am ANS-1 Recent Trends and Directions in Historic Preservation. JOHN A. SCAFIDI, Bureau of Historic Preservation, Division of Archives, History and Records Management, Department of State, Tallahassee 32301. Historic preservation is undergoing interesting and significant changes. It is no longer a movement, but has assumed the aspect of a fact of public and private sector life. The recent origins and present direction of historic preservation programs are examined with special reference to Florida. Forces for change are examined and the roles of advocacy groups in determining the presence and possible future courses of historic preservation activity are discussed.

9:20 am ANS-2 Archaeology and the Spanish Mission System in Florida: 1565-1704. ROCHELLE A. MARRINAN, Dept. of Anthro., Fl State Univ., Tallahassee, Fl 32306. The Spanish mission system in Florida effectively began with the settling of St. Augustine in 1565. Enduring into the 18th century, the mission effort initially involved aboriginal peoples occupying the coastal strand. Later, a chain of missions extending from St. Augustine to Pensacola was established. In full flower during the 17th century, the mission effort resulted in profound changes for the native population. Anthropologists have long been interested in the dynamics of acculturative processes. Archaeological investigation, coupled with documentary research, offers an opportunity to study the results of long-term interaction between Spaniards and Indians under the continuing threat of British intervention.

9:40 am ANS-3 Manasota: Which Way to the Border? KENNETH W. HARDIN AND HARRY M. PIPER, Piper Archaeological Research, Inc., St. Petersburg 33731. Although researchers have tentatively established the temporal parameters for the archaeological manifestations of the Manasota culture phase at coastal sites of the Central Peninsula Gulf Coast (ca.1200 to 2500 B.P.), there continues to be confusion as to its geographic extent.The problem can be attributed to:1) a previous paucity of data from inland sites, 2) an inconsistent use of culture phase defining criteria, and 3) a failure to consider and to derive useful archaeological measures of culture boundary mechanisms. In light of these factors, an examination of new data from inland sites and a review of coeval coastal site data leads to a placement of Manasota in space. This synchronic evaluation indicates settlement-level interassemblage variability but shared culture content. The refinement of Manasota cultural boundaries also furthers our understanding of the prehistory of the Peace River drainage, which has variously been described as a no man's land and as a center of political power.

10:00 am BREAK

10:20 am ANS-4 Centrality and the Prehistoric Landscape. BRENDA SIGLER-EISENBERG, Florida State Museum, Univ. of Florida, Gainesville 32611. In a recent article Barton (1978:44) states that exchange and the entrepreneurial role are basic features of the achievement of centrality. This paper examines the institutional framework of central place development during the early Formative period of north-central Florida. Specifically, it is argued that geographical centrality was achieved in two ways. First through an operationally specialized component of lineage development--central mound burial. Secondly, as a result of shamanistic entrepreneurs, a growth sector is created within the subsistence economies of the early Formative period through the production and consumption of religious/ceremonial commodities. Hence, the entrepreneur occupies an institutional niche whereby he provides both a central service religious function and becomes an economic agent who captures a role in exchange. The degree of centrality and stability of the central place are examined with respect to their ability to generate higher order activities.

10:40 am ANS-5 Proton Induced X-Ray Emission Analysis of Archaeological Ceramics. GLEN H. DORAN, Florida State University, Department of Anthropology, Tallahassee 32306. PIXE analysis of archaeological ceramics from Florida is effective in separating sherds from different geographic areas. PIXE analysis is extremely cost effective and can provide archaeologists with an inexpensive and useful technique of elemental analysis. Differences in chemical composition allow some geographic areas to be distinguished on simple presence and absence and nonoverlap in minimum and maximum values. Other areas are effectively separated with discriminant function analysis. The data base being developed at Florida State University now includes archaeological ceramics from Florida, Alabama, Georgia, Texas and New Mexico as well as historic materials from around the world and includes over 200 sherd samples.

11:00 am ANS-6 Food for Thought? The Depiction of Ritual Animals by Eastern United States Indians, 500 B.C.-A.D. 500. JERALD T. MILANICH, Florida State Museum, Department of Anthropology, Gainesville 32611. In a recent study Vernon J. Knight, Jr., created a model explaining why specific animals were portrayed in the ceramic art of the Weeden Island culture. Knight hypothesizes that the animals depicted were those which received special taxonomic status because of anomalous behavior (relative to folk classification). The classification schema and ritual treatment of the animals are viewed as metaphorically related to social distance, marriage, residence, and charnel activities. Knight's model is tested using the art of roughly contemporary peoples--including Belle Glade, Adena, and Hopewellian cultures--by comparing the archaeological contexts of the art and the animals portrayed with similar parameters of the Weeden Island culture.

11:20 am DISCUSSION

FRIDAY 3:00 pm GCS 217
SESSION A: Medical Anthropology
L. LIEBERMAN, University of Florida, presiding

3:00 pm ANS-7 Vision Perception through the Physiology of Emotion. GREGORY TOOTHMAN, Department of Anthropology, Florida State University, Tallahassee, FL 32306. While we recently became aware that a number of affective disorders, including depression and schizophrenia, involve predisposed biochemical misfunction, rarely have the neurosciences looked at similar altered states as self-induced processes. Furthermore, the role the emotions play in this formulative process is frequently overlooked. The anthropological literature abounds with examples of rigorous activities imposed on would-be visionaries. George Devereux predicted that the shaman, for example, was essentially a pathological character, although he might be accepted by his society. The interplay of emotion and cognition is considered to have significant ramifications in the formulation of visionary consciousness. Religious ascetic discipline is shown to be a methodology in achieving altered perception. Finally, cybernetic and synergy theory are applied to give a more comprehensive picture.

3:15 pm ANS-8 Maternal Perception of Premature Infant Temperament. ANGELA E. SCOGGIN, R. J. GAGAN, AND J. M. CUPOLI, Department of Pediatrics, University of South Florida College of Medicine, Tampa, FL 33612. A modified schedule of the Carey Infant Temperament Questionnaire was administered to 43 predominantly single, lower SES mothers of premature infants. Birthweights ranged from 1000 to 2000 grams and neonatal intensive care was required. At an average of 2.5 months chronological age, 74% were found to be "difficult babies" according to mothers' perceptions. This figure is substantially higher than the 11% found in Carey's original sample of middle class infants at 3.5 to 8.5 months of age. Mothers' perceptions of "temperamental behaviors" could affect the developing parent-infant relationship soon after birth. Lack of economic and social supports, and prolonged hospitalizations could exacerbate an already stressful situation. Relationship-focused early intervention was presented as a means for increasing parental confidence and facilitating positive parent-infant interactions. Funded by State of Florida, Department of Health and Rehabilitative Services, Administration on Developmental Disabilities.

3:30 pm ANS-9 Issues and Policies Pertinent to the Right to Die. PHILLIP E. GRACE, Dept. of Antropology, University of South Florida, Tampa, 33620. Since the turn of the century there have been many developments within our society that have precipitated a growing demand for open discussion and public policy addressing the Right to Die issue. Advances in medical technology, the increasing population, unstable economic conditions, and changes in social values and within the social structure itself are just some of the factors that have forced us to take a long, sober look at a subject that, until fairly recently, had been socially taboo. Decisions are being made daily that necessitate the clarification of individual rights regarding death. These decisions are frequently challenged by individuals, organizations, and institutions, becoming the focus of a debate that has profound ethical, legal, and moral implications for our society.

3:45 pm BREAK

4:00 pm ANS-10 Consumer Participation in Policy Formulation for Health Maintenance Organizations. DORLE G. KIND, University of South Florida, Department of Anthropology, Tampa 33620. Health Maintenance Organizations serve specialized consumer groups; therefore, consumer participation in the formulation of a health maintenance organization's policy warrants examination. In the context of consumer participation, viable roles may be available to the practicing anthropologist. Before these potential roles for both consumers and anthropologists are examined, a brief definition of a health maintenance organization is given in addition to what an HMO purports to maintain: health. Consumers can participate to varying degrees in an HMO's policy formulation, ranging from advisory roles to direct involvement in the planning stages for the organization. Depending on the degree of consumer participation and the stage at which the consumers begin participating in their health maintenance organization's policy formulation, the practicing anthropologist may assume the role of advocate, policy formulator, and evaluator to provide consumers with the most effective HMO to meet their needs.

4:15 pm ANS-11 Communication Order, Disorder, and Logical Ontologies in Anthropological Discourse. KEN HOECK, Department of Anthropology, Florida State University, Tallahassee, FL 32306. Ongoing research has been conducted investigating the dynamics of the subjective/objective discourse in anthropological analysis. The role of cybernetic processes is amplified in this paper to demonstrate the sequencing problems of anthropological argumentation. The objective foundations of anthropology are reconsidered using various sources including the writings of Gregory Bateson, French deconstructivism, and ethnopoetics. Finally, while the role of the personal cannot be separated from the investigative process, to consider these problems from conventional pragma-investigation, is to pursue an illusion. Our discussion will pursue and touch on the frequently poetic nature of anthropological illusion.

SATURDAY 8:15 am GCS 111
SESSION B: Physical Anthropology and Archaeology
W.J. KENNEDY, Florida Atlantic University, presiding

8:15 am ANS-12 Age Determination from the Rib. SUSAN R. LOTH AND M. YASAR İŞCAN, Department of Anthropology, Florida Atlantic University, Boca Raton 33431. The authors (Loth et al., 1983) previously established the sternal extremity of the rib as a reliable indicator of skeletal age at death using a system of component analysis to quantify metamorphoses at this site. The current study presents an alternative method that can provide a rapid, accurate estimation of age from the rib. Morphologic changes directly observed at the medial articular surface of the rib formed the basis for separating the specimens (N=118 White males) into nine phases (0-8). These changes focused on the development of a pit, its depth and shape, and features of the rim and walls surrounding it, along with overall bone quality. Results indicated that age can be estimated to within 3 years for individuals 17-28, and within 10 years through age 72.

8:30 am ANS-13 Dental Pathology of the Highland Beach, FL Indian Population. J. SCHOEN, R. ISLER, AND M. Y. İŞCAN, Florida Atlantic University, Boca Raton 33431. This study deals with the dental pathology of prehistoric S.E. Florida Indians dating from 800-1200 A.D. The sample is composed of 108 adult individuals (N=46 males, N=62 females). The hunting of small game animals, exploitation of marine resources, and gathering of plants was the main subsistence activity of this group. This study presents the results of an examination of nine dental lesions. Caries were minimal (1.1%) without sexual differences. Hypoplasia was the same in both sexes. The combined percentage of ante mortem tooth loss was 10%. Periodontal abscesses were more prevalent in males (6.5%) than in females (4.8%). The rate of attrition was less common in females (53%) than in males (68%) at the level of "dentin visible" to "worn to neck". These results are in agreement with those on a similar precontact coastal American Indian population.

8:45 am ANS-14 An Investigation of Skeletal Remains from the Ormond Beach Mound. JUNE G. SAGER, Department of Anthropology, Florida Atlantic University, Boca Raton 33431. The Ormond Beach burial mound of Volusia County has been the focus of an intense preservation effort after nearly being destroyed during the spring of 1982. Twenty two burials were recovered containing single or multiple individuals. The fragmentary skeletal remains were commingled making detailed analysis difficult. The purpose of the study was to assess this material morphologically and metrically to obtain a paleodemographic and paleopathological profile. All individuals were adult and the bones indicated relatively good health. Approximately 35% were male, 38% female and 27% unknown. There were several pathological lesions observed in five individuals. These included evidence of osteomyelitis, arthritis, osteoid osteoma, fractures, syphilis and several dental lesions. Arthritis was more common than others. This paper not only illustrates these findings, but compares this population with those of other prehistoric populations of Florida.

9:00 am ANS-15 Acquiring Archaeological Properties. MICHAEL J. HANSINGER, SW Fl Field Assoc., The Florida State Museum, P. O. Box 777, Ft. Myers 33902. In 1981-82 the Federal Bureau of Land Management (BLM) had the problem of how best to divest itself of some 800 acres of SW Fla. lands and islands with many archaeological sites. Invited to accompany their archaeological survey, I briefed on other government interests in the areas, and coordinated the Museum's position. A consensus was reached that any government unit with management already on hand should have first crack at any property, unopposed by the other units. Our focus was on responsible custodianship and archaeological preservation. The Interior Dept. then suggested alternative dispositions, to include sale to private bidders. These islands are scenic gems and near expensive development. Public meetings followed. We alerted other concerned parties. The response much favored the original plan and the desired transfers are now taking place. The Museum believes these transfers are the most important archaeological acquisitions in the public interest in 1983. BLM staff and many others throughout Florida earned a full measure of praise for this success.

9:15 am BREAK

9:30 am ANS-16 Five Years After: An Analysis of Dade County's Cultural Resource Management Program. ROBERT S CARR, Dade County Historic Preservation Division, 90 S.W. 8th St., Room 309, Miami 33130. In 1979, an archaeological survey of sites in metropolitan Dade County was implemented. A total of 350 sites was assessed. Since 1979, 15 of these sites have been adversely affected or destroyed by development. This paper describes the methods and effectiveness of the program to preserve, monitor and salvage archaeological sites within a large metropolitan area.

9:45 am ANS-17 Lithic Waste Flake Analysis: Stone Tool Manufacture During the Florida Archaic. RICHARD ESTABROOK, Department of Anthropology, University of South Florida, Tampa 33620. The lithic debitage assemblage from the middle Archaic component (ca. 7000 to 5000 B.P.) of the Ranch House site (8Hi452) is analyzed using flake attribute categories felt to be sensitive indicators of stone tool manufacture technologies. These attributes include striking platform faceting, cortex on the dorsal surface, thermal alteration, and flake size. This investigation is incorporated into the study of three interdependent processes: stone tool manufacture trajectories, lithic raw material procurement and differential exploitation, and the use of thermal pretreatment, or heat alteration, in stone tool manufacture. Mass analysis, attribute analysis, and an analysis paradigm are employed to derive behavioral inferences from large quantities of lithic debitage.

10:00 am ANS-18 A Defense of the Inductive Approach in Archaeological Theory-Building. DAVID M. BREWER, Anthropology Department, Florida State University, Tallahassee, Florida 32306. Rather than an indictment of the hypothetico - deductive method, this paper presents a case for the use of induction as a proper means of developing useful hypotheses for testing. Given the field-gathered data-base of facts, the archaeologist must depend on training, observation, and educated guessing to form ideas through process and pattern recognition that will subsequently be either accepted, rejected, or modified. It will be shown that, in many instances, the means whereby artifacts, features, etc. are ascribed to past behavior can often be seen to be the result of insight and the ability to see through the obvious.

10:15 am ANS-19 The Spatial Organization of a Late Fort Walton Farmstead at the Velda Site, Leon County, Florida. JOHN F. SCARRY, Bureau of Archaeological Research, The Capitol, Tallahassee 32301-8020. Archaeological investigations were conducted at the Velda Site, a late Fort Walton (Velda phase) site in Leon County, Florida. The field investigations comprised three distinct data acquisition programs; controlled surface collection of aboriginal artifacts; limited stratigraphic test excavations; and broad horizontal excavations. The excavations revealed an entire Velda phase farmstead thought to date to the period AD 1450-1600. This report presents preliminary results of an examination of the spatial organization of that farmstead, the lowest social organizational level of the protohistoric Apalachee society. It examines questions on refuse disposal patterns, spatial organization house construction and broader settlement patterning.

SATURDAY 11:00 am GCS 111
SESSION C: Cultural Anthropology
A. PAREDES, Florida State University, presiding

11:00 am ANS-20 "I Teach" - What Does It Mean? BARBARA E. ROTHSTEIN AND BARBARA S. SPECTOR, Southeastern College of Osteopathic Medicine, 1750 N.E. 168th Street, North Miami Beach 33162; School of Education, Florida International University, Bay Vista Campus, North Miami 33181. Interviews with teachers in our society revealed that there are many different perceptions of the phrase "I teach." Further discussions indicated that these perceptions may be derived from past experiences as a student, feedback from members of the role set, and varying needs for creative outlets, intellectual stimulation, and variety. Evidence emerged that conflict may occur when perceptions derived from various sources are not congruent with each other.

11:15 am ANS-21 Amish Society: Increased Productivity through the Expansion of the Internal Means of Production. NANCY L. WILLIAMS, University of Central Florida, 3070 Riverbrook Dr., Winter Park 32792. The Amish culture is examined; productivity is viewed as a process of internal expansion as a means of permitting increased reproductivity as opposed to the American cultural 'norm' of productivity through the expansion of external means of production. The development of the Amish are explored; also the effectiveness of their infrastructure. The Amish avoidance of dependency producing technology is analyzed and viewed as a 'school of skills'. Anomalies in Amish life are also explored, as well as the future for the Amish society.

11:30 am ANS-22 Controlled Change in a Hotel Setting. LUH ANN MCDEVITT, 1704 S.E. 2nd Street, Pompano Beach, Florida 33060. Anthropological concern with controlled change in modern societies has grown in recent years. In this study, the implementation of a program of Quality Assurance in two major dining facilities of a large resort hotel is positively related to a decrease in unsatisfactory guest comments. Quality Assurance is defined as the consistent delivery of services in accordance with established standards. These standards include both measures and qualitative descriptions of performance. This study involves an analysis of guest comment cards for a period of sixteen months. For eight months, the program of Quality Assurance was in effect. The guest perception of the hotel product is seen through the use of the guest comment cards. Expectations are that this program will lead to improvement in communications and clarification of job expectations, seen as desirable objectives.

11:45 am DISCUSSION

SATURDAY 12:00 noon GCS 111
BUSINESS MEETING: Anthropology
J.R WILLIAMS, University of South Florida, presiding

ATMOSPHERIC AND OCEANOGRAPHIC SCIENCES

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

SATURDAY 8:30 am GCS 208
N.P. SMITH, Harbor Branch Foundation, presiding

8:30 am AOS-1 Total Atmospheric OH Measurements: 26°N (Boca Raton, FL), 40°N (Fritz Peak, CO) and 65°N (Poker Flat, AK). E.B. BURNETT AND C.R. BURNETT, Florida Atlantic University, Boca Raton, 33431. Measurements of total atmospheric OH have been made during the January-May period in 1980, 1981 and 1983 from Boca Raton, FL, using a high-resolution Pepsios spectrometer. Data has also been obtained at 40°N, 1976-83 and from 65°N, 1983. Total OH at 26°N was a full 50% above corresponding values for 40°N in 1980 and showed a steady decrease to about 40°N levels by 1983. Poker Flat (65°N) values are about 30% higher than corresponding 40°N levels. Data from 40°N shows a seasonally varying diurnal asymmetry of 50% which closely tracks the well-documented seasonal behavior of total ozone. The diurnal behavior of data from 26°N (January-May) is similar to the fall behavior of OH at 40°N. The observed geographic differences in the behavior of OH are not addressed by recent theories of atmospheric photochemistry. Some of the possible mechanisms will be discussed. This research is supported by NSF grant ATM7924585, Florida Atlantic University and the NOAA/ERL Aeronomy Laboratory.

8:45 am AOS-2 Transport and Reactivity of the Airborne Toxins of *Ptychodiscus brevis*. ALBERT L. MYERSON AND RICHARD H. PIERCE, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. A laboratory technique has been developed which simulates the phenomenon whereby red tide toxins are transported to the shore. Solutions are aerosolized in a Pyrex vessel by means of air bubbled through dispersion tubes. This creates an aqueous aerosol containing NaCl or dissolved pseudotoxins (PTX) which are captured on quartz filters and analyzed. PTX choice was based on the known brevetoxin structure, BTX-B. It contains 11 contiguous transfused ether rings which led to the choice of dicyclopentano-18 crown-6 (PT-B) which contains 6 contiguous ethers. Data show that the crown compound has exceptional ability to form aerosol and to diminish bubble size. If these unusual surfactant properties are due to structure in common with BTX-B, they may be important in fish gill damage and in effective aerosol transport. Studies will continue with crown compounds and then with *P. brevis* cultures. Support from the State of Florida and the assistance of E. McFadden and M. Krzyzanowski, are gratefully acknowledged.

9:00 am AOS-3 An Introduction to Monostatic and Bistatic Acoustic Radar - Its Principles and Selected Applications. DEWEY M. STOWERS JR., University of South Florida, Fowler Avenue, Tampa, FL 33620. An investigation into selected practical uses of monostatic and bistatic acoustical radar was initiated in regard to urban climatology. A description of the installation, major components, and the function of the sounders is followd by an evaluation of recorded soundings of meteorological phenomena in the lower atmosphere. Emphasis was placed on the measurement of surface inversions, radiation fogs and convectional activity.

9:15 am AOS-4 Oil Ash as a Waste Material; The Disposal Options. Vincent T. Breslin. Department of Oceanography and Ocean Engineering, Florida Institute of Technology, Melbourne 32901. Oil ash is the residue remaining after oil is combusted in electric power generating utilities. Elements such as calcium, iron, sulfur and vanadium are present in large amounts in oil ash. Several minor elements including arsenic, zinc and copper appear to be enriched in oil ash. Due to the presence of these toxic elements associated with oil ash, the ash must be disposed of in an environmentally acceptable manner. Oil ash is currently disposed of in contained landfills. However, due to growing concerns over possible contamination of the Florida's shallow aquifers, alternative methods for the disposal of oil ash are being sought. Presently, at F.I.T., work is underway to chemically and physically stabilize oil ash. If the stabilization process is successful, offshore artifical reefs may be constructed with this material.

9:30 am AOS-5 Stabilization and Engineering Properties of Oil Ash. David F. Mazurek. Department of Civil Engineering, Florida Institute of Technology, Melbourne 32901. Investigations on the stabilization of utility produced oil ash wastes for possible use in offshore artificial reef construction were conducted. The oil ash was found to lack the pozzolanic reactivtiy found in coal fly ashes. Physical properties including specific gravity of solids, grain size distribution, loss on ignition, and moisture density characteristics further show a significant difference between oil ash and coal fly ash. The stabilization of oil ash by enrichment with a pozzolanically reactive coal fly ash and the addition of lime and cement was examined. The engineering properties of the mixes will be discussed.

9:45 am AOS-6 The Importance of Interlaboratory Calibration for the Determination of Selected Hydrocarbons in Marine Samples. ROBERT C. BROWN and RICHARD H. PIERCE., MOTE MARINE LABORATORY, 1600 City Island Park, Sarasota 33577. Adequate evaluation of the extent and duration of petroleum contamination in the marine environment requires the effort of many investigators at different research institutions. With large numbers of environmental analyses to be performed, a common base is needed for comparison of results. Intercomparison of results is established through interlaboratory calibration exercises. Two such studies were conducted by this laboratory. The results of these exercises will be discussed along with standardized procedures and the reporting of data.

10:00 am BREAK

10:15 am AOS-7 A Comparative Study of Trace Metal Pollution in the Ivory Coast and Florida. ISSIFOU KOUADIO, POGBAN TOURE AND JOHN H. TREFRY, Department of Oceanography & Ocean Engineering, Florida Institute of Technology, Melbourne, Florida, 32901. The east coast of Florida has a similar hydrographic and climatic environment to that of the Ivory Coast, West Africa. Rapid municipal and industrial growth in both areas may be followed by the onset of pollution. To identify potential trace metal pollution problems at an early stage of growth, concentrations of Cu, Fe, Hg, Mn, Pb and Zn in sediments from the Lagoon Ebrié, Ivory Coast and Port Canaveral and the Indian River Lagoon, Florida are being determined. Near the capital city of Abidjan, Ivory Coast sediment Cu, Hg, Pb and Zn levels are as high as 86 µg/g, 180 ng/g, 250 µg/g, and 560 µg/g respectively. Away from urban areas, natural levels of 10 µg/g, ~2 ng Hg/g, <10 µg Pb/g, and 6 µg Zn/g are observed. Available Florida data show Pb and Cu levels as high as 30 and 200 µg/g in selected harbors.

10:30 am AOS-8 Radiographic determination of gut transit time in the juvenile lemon shark, *Negaprion brevirostris*. ANNA L.RAMSEY AND S.H. GRUBER, RSMAS/Univ.of Miami, Miami,Fl.33149. As part of an overall bioenergetic study of lemon sharks we measured gut transit time of a standard meal at 4 feeding levels: 1) constant 50g meal; 2) 2.7% body weight per meal(below maintenance ration); 3) 6.2% bw(maintenance); 4) *ad libitum*. Meals consisted of bluerunner(*C. chrysos*) steaks to which 2g of radiopaque $BaSO_4$ had been added. Sharks(0.9-1.9kg) maintained in recirculating tanks at 25C°and 30‰were individually x-rayed at 3h intervals. In all cases (19 sharks;4 feeding levels) evacuation was completed within 72-80h. The minimum gut transit time as determined by dyed meals was approximately 14h. Thus, to measure assimilation efficiency, a shark must be starved for 4 days, fed, and fecal collection maintained thereafter for at least 80h. Supported by NSF Biological Oceanography OCE8309831 to SHG

10:45 am AOS-9 Seasonality, Specificity and Geographic Distribution of Benthic, Toxigenic Dinoflagellates in the Florida Keys. JEFF W. BOMBER AND DEAN R. NORRIS, Florida Institute of Technology, Melbourne, FL 32901. Several dinoflagellate species associated with ciguatera were monitored for eleven months at five base stations and several other subsidiary stations in the Florida Keys. Dinoflagellate density per gram of macroalgal substrate was assessed throughout the study period. Additional substrate analysis was performed on inorganic substrata. Planktonic concentrations, salinity and temperature were also monitored. Statistical and descriptive analyses of the data are correlated and discussed. We thank the Oceanography and Ocean Engineering Department, Florida Institute of Technology and the National Marine Fisheries Service for support.

11:00 am AOS-10 Computer Simulation of the Effect of Causeway Removal at the Port Orange Causeway on the Hydrology of the Halifax River, Volusia County. MICHAEL J. GILBROOK AND NOEL O. WAMER, Florida Department of Transportation, P.O. Box 47, DeLand 32721. Since the construction of the Port Orange Causeway and Bridge in 1951, concern has been expressed that the causeway restricts tidal and wind-driven circulation in the Halifax River. A two-dimensional hydrological model of the estuary was used to simulate the effect of removing 60 m or 500 m sections of causeway under dry weather and storm conditions on the movements of simulated "inertialess particles" which were tracked by the model to provide a measure of tidal flushing. No significant increase in the tidal flushing rate of the upper estuary was predicted for either causeway removal alternative under the dry weather conditions, and the rate of tidal flushing for some portions of the estuary was reduced by causeway removal in the storm simulations. Changes in tidal stages and velocities with causeway removal were relatively small and confined to the immediate vicinity of the causeway.

11:15 am AOS-11 Routinely Collected Weather Data for Simulating Air-Water Heat Energy Exchanges in Shallow Lagoons. NED P. SMITH, Harbor Branch Foundation, Rt. 1, Box 196, Ft. Pierce, FL 33450. Standard meteorological observations from Kennedy Space Center Shuttle Airport at Port Canaveral are used to simulate air-water heat energy exchanges in Banana River Lagoon during a 98-day period in summer, 1980. Air temperature, dew point, cloud cover, wind direction and atmospheric pressure recorded at the weather station are assumed to represent conditions at the study site itself, 4 km away. Wind speed was modified using a trivariate regression of tabular data involving over-water fetch, air-water temperature differences and wind speed at the weather station. Computed daily net temperature changes match observations closely, indicating that day-to-day variations are in response to local processes, and that these processes are being modeled faithfully by routinely collected weather data.

FRIDAY 11:30 am GCS 208
BUSINESS MEETING: Atmospheric and Oceanographic Sciences
N.P. SMITH, Harbor Branch Foundation, presiding

BIOLOGICAL SCIENCES

FRIDAY 9:30 am GCS 204
SESSION A: Physiology
J.M. LAWRENCE, University of South Florida, presiding

9:30 am BIO-1 The Effects of Temperature on the Activity and Kinetics of Pyruvate Kinase in the Pyloric Caeca of Luidia clathrata (Say) (Echinodermata: Asteroidea). S. WATTS, L. WEAKLAND, AND J. LAWRENCE, Department of Biology, University of South Florida, Tampa 33620. The specific activity (SA) of pyruvate kinase (PK) was 4.9 uM/min/gFW at an assay temperature of 25°C. The Q_{10} of the SA of the PK over the temperature range of 13-17°C was 2.94; from 17-25°C, 2.3; from 25-32°C, 2.4. The Km of PK for PEP and ADP was 0.16 and 0.15 mM, respectively, at an assay temperature of 25°C. Km values did not change significantly over the temperature range of 13-32°C. The response of the SA and Km of PK to temperature is similar to those found for other echinoderm enzymes (triosephosphate isomerase, malic dehydrogenase, and the electron transport system). These data indicate that there is little or no instantaneous thermal modulation in these species.

9:45 am BIO-2 Activity of Carbonic Anhydrase of the Plumula of the Tooth of Lytechinus variegatus (Lamarck) (Echinodermata: Echinoidea). CHANG-PO CHEN, Department of Biology, University of South Florida, Tampa 33620. The activity of carbonic anhydrase, which catalyzes the reversible hydration of carbon dioxide, was measured by the technique of Maren (1960, J. Pharma. Exp. Therapeutics, 130: 26-29). The activity in the plumula ranged from 2.69 to 7.61 units/g wet weight of the plumula with an average of 4.56 and a standard deviation of 1.68 (the unit is the activity necessary to halve the time of the uncatalyzed reaction). This carbonic anhydrase is sensitive to acetazolamide, a specific inhibitor of carbonic anhydrase.

10:00 am BIO-3 The effects of Feeding Experience Upon Feeding Rates of Lytechinus variegatus (Lamarck) (Echinodermata: Echinoidea) Upon Artificial Foods of Different Composition. T. S. KLINGER, Univ. of South Florida, Tampa 33620. Lytechinus variegatus were fed artificial agarose foods containing either the red alga Gracilaria verrucosa or the marine angiosperm Thalassia testudinum following different feeding schedules over a period of 12 days. Increases in feeding rates indicated facilitation of feeding responses with familiarity or increased dexterity in manipulating food items with experience but not discriminative learning. Feeding rates upon the artificial foods prescind over time, becoming greater with repeated feedings. Feeding rates change slowly, individuals tend to maintain high or low rates of consumption. Neither the feeding rates of individuals fed one type of artificial food for 6 days and subsequently switched to the other, nor the feeding rates of individuals fed a single type of food for 6 days and subsequently proffered a mixture of both types of food items, changed in a way suggestive of changes in prey choice brought about by ingestive conditioning. Supported by a Grant-in-Aid of Research from Sigma Xi.

10:15 am BIO-4 Chemoreception in Luidia clathrata (Say) (Echinodermata: Asteroidea). JAMES B. McCLINTOCK, Dept. of Biology, Univ. of South Florida, Tampa 33620. Luidia clathrata has chemoreceptive responses to compounds most closely aligned with its dietary preferences. Luidia clathrata responded most strongly to L-glutamic acid, L-cysteine, L-cystine, L-isoleucine and betaine, compounds indicative of fleshy foods. Sugars (maltose, sucrose, lactose), compounds indicative of plant and detrital foods, elicited some responses, but these compounds are generally less stimulatory than amino-acids. The excretory product ammonium, indicative of the metabolic activity of live prey, elicited a weak response. Chemotactic response curves were clearly concentration dependent. Concentration response curves for L-cysteine, L-glutamic acid, and L-isoleucine are steeply sloped and have RD-50 values within the range of 1×10^{-8} and 1×10^{-5} M. These results suggest that chemically mediated teloreception is an important component of both search behavior and food discrimination for this asteroid.

10:30 am BREAK

10:45 am BIO-5 The application of indirect methods to calculate absorption efficiencies of echinoids (Echinodermata). JOHN M. LAWRENCE, Department of Biology, University of South Florida, Tampa 33620. The use of the relation, $U' = F' - E'/F'$ (where U' is the indirectly calculated absorption efficiency; F' is the percentage of a component in the food; and E' is the percentage of a component in the excreta) closely approximates the absorption efficiency calculated by the Conover formula only when the level of organic material in the food is very low. The Conover formula, $U' = (F' - E')/ (1 - E')(F')$ (where F' is the ash-free dry weight: dry weight ratio in the food, E' is the same ratio in the excreta expressed as a percentage) assumes that there is no change in the amount of inorganic material in the gut contents in the passage through the gut. The data of Larson et al. (1980, Mar. Biol.) can be used to show that this basic assumption was not correct in their study with the echinoid, Strongylocentrotus droebachiensis.

11:00 am BIO-6 Nutrition of Ghost Crabs Fed Prey of Different Organic Composition. BRUCE D. GRAHAM AND RICHARD L. TURNER, Department of Biological Sciences, Florida Institute of Technology, Melbourne 32901. Predators often must deal with prey populations that vary seasonally in quality (organic composition) as well as quantity. To determine the effects of food quality on nutrition of Ocypode quadrata, two groups of 20 male crabs were fed prey of different food quality: bivalves (Donax variabilis) were higher in carbohydrate and protein than mole crabs (Emerita talpoida). The organic composition of the hepatopancreas and of hepatic and gonadal indices were measured for Ocypode fed Donax or Emerita ad libidum and for Ocypode taken from the field at 30-d intervals over a 120-d period. Organ indices increased faster in Emerita-fed ghost crabs. The hepatopancreatic composition of Ocypode closely reflected the composition of the prey. Biochemical changes in field and Emerita-fed crabs were more similar to each other than to Donax-fed crabs. The nutritional condition of Ocypode should change in the field as the comparative availability of its two major prey—Donax and Emerita—change seasonally.

11:15 am BIO-7 Structure of the gonad and release of gametes of the coelomic brooding sea cucumber Synaptula hydriformis. W. A. ESTABROOKS AND R. L. TURNER, Dept. Biol. Sci., Florida Institute of Technology, Melbourne 32901. Synaptula hydriformis is a small, coelomic brooding sea cucumber which is an epiphyte in shallow waters of the Western Atlantic Ocean. This species is hermaphroditic. Eggs ripen beneath a simple gonadal wall and are separated from the inner, spermatogenic region by a thin partitioning layer composed of squamous epithelial cells, spermatogonia and vacuolated cells. The gonoduct is composed of two layers of cuboidal cells and ends blindly in the body wall in a subepithelial vesicle. The gonopore is a temporary structure, opening externally only during spawning. Sperm are released externally through the gonopore. Eggs rupture the gonadal wall and are released into the coelom, where development occurs. This species is not a simultaneous hermaphrodite. Sperm from other individuals probably enter the coelom by way of pores in the wall of the rectum. Supported in part by a grant from the William Bowers Estuarine Research fund to W. A. E..

11:30 am BIO-8 Macrocallista nimbosa: A molluscan model for the study of urolithiasis. WILLIAM J. TIFFANY III and T.B. LARKIN, Florida Department of Health and Rehabilitative Services, Manatee County Public Health Unit, 202 6th Ave. E., Bradenton, FL 33508. Calculi (kidney stones) are ubiquitous in Macrocallista nimbosa, regardless of age or geographic location. The calcium phosphate calculi begin as intracellular stone precursors within the renal tubule walls and subsequently continue development as intraluminal concretions. The kidney tubule epithelial cells are ultrastructurally similar to those of the human proximal tubule (the most probable area responsible for the genesis of urinary calculi in man). These observations suggest that M. nimbosa is well suited as a model for the study of urolithiasis, with relevance to the human condition.

FRIDAY 3:00 pm FLH 313
SESSION B: Marine Biology
C. LUER, Mote Marine Laboratory, presiding

3:00 pm BIO-9 An Assessment of Heavy Metal Concentrations in Mullet (Mugil cephalus) from the Tampa Bay Area. KIRBY S. OLSON AND JOHN REYNOLDS, Department of Biology, Eckerd College, St. Petersburg, Florida 33733. Adult specimens of Mugil cephalus were obtained from several inshore areas around Tampa Bay. Samples of liver, kidney, and muscle tissue were digested in acid and analyzed for copper, lead, mercury, and cadmium using a Varian AA-1475 flame atomic absorption spectrophotometer. High levels of construction work, boat traffic, and other human activity in the Tampa Bay area may result in elevated concentrations of heavy metals and other pollutants in local marine organisms. Heavy metals tend to accumulate in liver and kidney tissues of teleosts; analysis of these tissues provides data on current pollution levels in the bay and forms a basis for comparison to other geographic areas or to the same area at a later date.

3:15 pm BIO-10 Hemopoiesis in the West Indian Manatee, *Trichechus manatus*. MARIA D. BAZZINI AND JOHN REYNOLDS, Department of Biology, Eckerd College, St. Petersburg, FL 33733 AND RICHARD ESSMAN, Bayfront Medical Center, St. Petersburg, FL 33701. West Indian manatees (*Trichechus manatus*) and other members of the order Sirenia, unlike most mammals, possess amedullary long bones. Histological examinations of the visceral organs, sternum and vertebral bodies showed that the primary site of hemopoiesis in the manatee is the vertebral bodies. The vertebrae contained the bone marrow and several diagnostic cell types including megakaryocytes, erythroblasts and myelocytes.

3:30 pm BIO-11 Abundance and Movement of Bottlenose Dolphins, *Tursiops truncatus*, in Tampa Bay, Florida, during 1983. BRADLEY L. WEIGLE, University of South Florida, Dept. of Marine Science, 140 7th Avenue South, St. Petersburg, FL 33701. Bottlenose dolphins in Tampa Bay were enumerated and photographed during 52 boating surveys from April through October, 1983. Of the 1,278 animals sighted, 115 (9.0%) were calves. More than 60 individual animals have been identified from photographs of scars, wounds, and natural markings on the dorsal fins. Population estimates, movement of individuals, and home range theory will be discussed.

3:45 pm BIO-12 Loggerhead (*Caretta caretta*) Sea Turtle Conservation Program. JENNY L. MAPES, Mote Marine Laboratory, 1600 City Island Park, Sarasota 33577. The objectives of Mote Marine Laboratory's sea turtle research program include defining the preferred nesting locations of sea turtles on the five barrier islands of Sarasota County, setting up natural hatcheries for transplantation of endangered nests, tagging adult female turtles to determine internesting intervals and reproductive productivity, and establishing mortality factors. Casey and Manasota Keys maintain the largest population of nesting loggerheads, attributable to the lack of development along their coastlines. Internesting intervals are approximatly 12 days with hatching achieved in about 80% of the eggs laid. Comparisons of 1982 to 1983 data show an increase in nests from 78 to 168 , an increase in hatchlings from 6,510 to 14,537, and a decrease in average number of days to hatching from 57 to 54. Factors such as the "no-name" storm of 1982 have had significant impacts on the local nesting population.

4:00 pm BIO-13 Sexual Maturation in the Clearnose Skate, *Raja eglanteria*. PATRICIA BLUM AND CARL A. LUER, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. The clearnose skate, *Raja eglanteria*, inhabits nearshore waters of the central Gulf coast of Florida during winter and spring, at which time mating and egg deposition take place. Since only mature animals come inshore to breed, information on sexual maturation is unavailable in the literature. Using offspring from laboratory bred skates, sexual development has been observed over the past two years with animals of known age. Males are recognized by the presence of claspers, which are identifiable even during embryogenesis, and remain small during the first year. The largest males can attain adult sized claspers in as little as 1-1/2 years and have been shown to possess mature sperm. Females can reach adult body size within two years but do not possess mature ova or well-developed shell glands.

4:15 pm BIO-14 Nurse Sharks of Big Pine Key: Preliminary Evaluation of the Success of 3 Types of External Tags. JEFFREY C. CARRIER, Dept. of Biology, Albion College, Albion, MI 49224. Of 71 nurse sharks (*Ginglymostoma cirratum*) and 30 lemon sharks (*Negaprion brevirostris*) tagged from Big Pine Key (Florida Keys), 14 different nurse sharks have been recaptured once and 2 animals have been recaptured twice. Eight of the recoveries (from 7 different animals) were from a group of 19 animals tagged with only stainless steel barbed tags. Of 38 animals tagged with both nylon barbed spaghetti tags and modified Carlin disc tags, 8 recoveries (from 7 different animals) were recorded and of these recoveries, 3 had both tags in place, 1 carried only the nylon-barbed tag, and 4 had only the disc tag. 19 animals have recently been tagged with all three tag types, but no recoveries have been reported to date. Photographic evaluation of recovered tags indicate greater success of steel tags and severe problems to growing animals from disc tags.

4:30 pm BIO-15 Distribution of Caridean Shrimp (Decapoda : Natantia : Caridea) in the Shallow Waters of Western Florida Bay. D. KRISTIN LARSON AND ANN P. RAMUS, South Florida Research Center, Everglades National Park, P.O. Box 279, Homestead, FL 33030. In conjunction with ongoing research on the settlement behavior of penaeid shrimp in Florida Bay, data has been collected for caridean shrimp. Species richness, distribuiton and abundance of caridean shrimp in shallow seagrass habitat boardering mangrove islands of Johnson Key Basin has been studied from November 1983 to the present. A series of transects, 20 meters long, were located perpendicular to the shoreline of the islands. Shrimp were collected from meter^2 plots located at regular intervals along the transects. Of six caridean shrimp species recorded, dominants included Thor floridanus, Hippolyte pleuracanthus, and Palaemonetes intermedius. Also, numbers of Tozeuma carolinense were observed to increase at offshore sites dominated by Thallassia testudinum. Total numbers of caridean shrimp were as high as 322 shrimp/m^2. Preliminary results indicate that greatest species richness and peak abundance of caridean shrimp occur at the Haladule wrightii and Thallassia transition zone.

4:45 pm BIO-16 Baseline Study of Coral Reef Scenescence, Injury, and Death. A. THORHAUG, G. TOWNSEND, AND F. BOOKER, Applied Marine Ecological Services, Inc., 1121 Crandon Blvd., Miami 33149. Despite many studies of growth of coral reefs, only a few qualitative studies of the death process have been carried out on non-polluted reefs. Baseline of natural processes are necessary prior to evaluating pollution impact. Reefs in the Florida Keys, Jamaica, Cayman Islands, and Bonaire were measured for morphological injuries and death (necrotic spots, bleached surfaces, discoloration, loss of polyps, and predator damage) as a function of species and depth. Results showed shallower corals to have more injuries than deeper corals. Type of injury and amount of dead tissue also varied with depth and species. Star (Siderastrea siderea) and brain (Montastrea cavernosa) corals were the predominant species and will be compared among sites.

FRIDAY 5:00 pm FLH 313
BUSINESS MEETING: Biological Sciences
T. SNELL, University of Tampa, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

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FRIDAY 3:00 pm FLH Lobby
POSTERS

Bottom Communities of Biscayne Bay. GARY R. MILANO[1]
Dade County Artificial Reefs. BENJAMIN J. MOSTKOFF[1]

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[1] Dade County Department of Environmental Resources Management, 909 SE 1st Ave., 4th Floor, Miami 33131

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FRIDAY 3:00 pm FLH 315
SESSION C: General
F. PUNZO, University of Tampa, presiding

3:00 pm BIO-17 Seasonal Population Variations in _Sigmodon hispidus_ in a Northeast Florida Flatwood. DIANE POWELL, CYNTHIA SMALL, AND CAROLE DeMORT, Department of Natural Sciences, Jacksonville, FL 32216. Five different sites (three community types) were trapped daily (Monday-Thursday) during the summer of 1983 using 17 Havahart traps. The sites were located on the University of North Florida Campus in Duval County, Florida. From this preliminary study it was determined that the scrubby flatwood was the preferred habitat of _Sigmodon hispidus_. Seasonal population variations were then studied during the following fall and winter using the mark and recapture technique. The date caught, sex, weight, body and tail lengths were recorded for each animal. These animals were then marked and released. Recapture efforts began in the middle of September and were carried on through January at bi-weekly intervals. A significant decline in the _S hispidus_ population occurred during fall and winter months. It is hypothesized that the population was experiencing a seasonal "low" and will increase during spring and summer months.

3:15 pm BIO-18 Regulation of Sexual Reproduction in Rotifer Populations. MELISSA R. CLEPPER AND TERRY W. SNELL, Division of Science, University of Tampa, Tampa 33606. The cyclically parthenogenetic life cycle of rotifers alternates between periods of sexual and asexual reproduction. Current models assume that sexual reproduction is an induced state which appears in parthenogenetic populations only in response to specific environmental cues. We examined the effect of 3 parameters, salinity, temperature and food level, on the appearance of sexual reproduction in the life cycle of the rotifer _Brachionus plicatilis_. At the extremes of the 3 variables examined, sexual reproduction ceased, leaving parthenogenesis as the sole means of reproduction. The reproductive response curves for asexual females are in each case broader than those of the sexual females. Our data suggests that a repressible model, in which sexual and asexual reproduction occur concomitantly unless sexuality is repressed by environmental extremes, better accounts for the appearance of sex in the rotifer life cycle.

3:30 pm BIO-19 Descriptive Analysis of a Mutant Temperature Sensitive _Drosophila melanogaster_. ANTHONY F. GABRIELE JR. AND D. VICKERS, University of Central Florida, Orlando, FL 32816. Genetic mapping of a temperature-sensitive _Drosophila melanogaster_ revealed the gene location on the right arm of the third chromosome between the curled (3-50) and stubbloid (3-58.2) loci. The permissive temperature is approximately 21°C and the restrictive temperature is approximately 28°C. There is a 20% to 25% embryonic lethality dependent upon maternal embryonic cytoplasm and independent of incubation temperature. The mutant temperature-sensitive flies exhibit abnormal alterations of the second, third and fourth abdominal sternite bristle patches and abnormal tergite development. Morphological studies suggest a variance in the sternite pattern from no separation of the patches to extreme division and separation of the patches dependent on the incubation temperature during the late third larval instar stage.

3:45 pm BIO-20 Effects of temperature upon the phenotype of a mutant Drosophila melanogaster. David Corey and David H. Vickers, Department of Biological Sciences, University of Central Florida, P.O. Box 25000, Orlando, Florida 32816. The effects of temperature upon the adult phenotype of a mutant strain of Drosophila melanogaster were measured. The mutant phenotype is one in which the abdominal sternites fail to develop properly with the resulting defects being most pronounced in the anterior abdomen and rarely extending posteriorly beyond the fifth abdominal segment. Deformities of tergites were also observed in about 2% of the flies. When cultured at 20.5^{o}C almost all (90+%) of the flies exhibited the mutant phenotype but as the culture temperature was increased the frequency of the mutant phenotype progressively decreased so that the situation was reversed at 28^{o}C and about 90% of the flies exhibited normal (wild type) abdominal sternites. Expression of the mutant phenotype was consistently more severe in females than in males at all temperatures investigated. This work was supported by grants from the University of Central Florida's Division of Sponsored Research.

4:00 pm BREAK

4:15 pm BIO-21 **The Combined Effects of Low Environmental pH and Temperature on the Survival Capacity of Tadpoles of the Southern Toad, Bufo terrestris. DAVID THOMPSON AND FRED PUNZO, Dept. of Biology, University of Tampa, Tampa 33606. Many species of toads breed in temporary ponds and streams which form from the accumulation of seasonal rains. These habitats are thus extremely susceptible to changes in temperature and/or pH. Tadpoles of Bufo terrestris exhibited almost 100% mortality at a pH of 3.2 at 20 deg C. At pH 3.0 , 100% mortality occurred at all test temperatures (10, 20 and 30 deg C). Over 80% of the tadpoles survived exposure to a pH range of 4.0 to 6.0 at all temperatures. Resistance to low pH was most pronounced at lower temperatures (10 and 20 deg C).**

4:30 pm BIO-22 **Temperature and Moisture Relationships of the Mangrove Tree Crab, Aratus pisonii (Decapoda). SCOTT BULGRIN, F. PUNZO AND W. PRICE, Dept. of Biology, University of Tampa, Tampa 33606. Studies were conducted to determine the effects of high and low temperature stress, moisture and period of exposure on the survival capacity of Aratus pisonii . The relationship between air and gill chamber temperatures was also investigated. High temperature stress was most pronounced under dry (12 % relative humidity) conditions at all periods of exposure (1 , 3 , 5 hours). At 44 deg C, there was 100 % mortality under relatively optimal moisture (72% rh) conditions after one hour of exposure. At 4 deg C and 72% rh, 100% mortality was found after 3 hours of exposure. The adaptiveness of A. pisonii to a semi-terrestrial habitat will be discussed.**

4:45 pm BIO-23 Retention of Learning Through Metamorphosis in the Holometabolous Insect, *Tenebrio obscurus* (Coleoptera : Tenebrionidae). RICHARD MALATESTA AND F. PUNZO, Dept. of Biology, University of Tampa, Tampa 33606. Studies were conducted using a shock-avoidance maze-learning paradigm to assess the degree of retention of learning through metamorphosis in the beetle, *Tenebrio obscurus*. Adults previously trained as larvae were retested and their performance was compared to that exhibited by adults without previous larval training. Results indicate that this species is able to learn a relatively complex maze, both in the larval and adult stages. In addition, adults previously trained as larvae showed a significant improvement in maze-learning ability when retested as adults as compared to the performance of adults without previous training thereby establishing the retention of learning through metamorphosis for this species.

FRIDAY 5:00 pm FLH 313
BUSINESS MEETING: Biological Sciences
T. SNELL, University of Tampa, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

SATURDAY 9:00 am GCS 117
SESSION D: Ecology
J. REYNOLDS, Eckerd College, presiding

9:00 am BIO-24 Seagrass Bed Distribution and Composition at Kennedy Space Center, Brevard County, Florida. JANE A. PROVANCHA, Bionetics Corp, Kennedy Space Center, FL. 32899, and R.M. WILLARD, Brevard County Environmental Engineering, Merritt Island, FL. 32953. Seagrass bed distributions were studied & mapped in the estuarine waters at Kennedy Space Center, Brevard Co, Florida during 1983. The purpose of the research was to document locations and composition of seagrass beds as part of a data base being compiled for a long term environmental monitoring program for J. F. Kennedy Space Center and Brevard County Environmental Engineering. Color infrared aerial imagery was obtained from an aircraft flown at 1850m in March of 1983. Ground truthing by boat and 23 permanent transects were employed to verify the grassbed locations and to quantify species composition, percent coverage and sediment texture. Results were obtained from north Banana River and south Mosquito Lagoon and established that *Halodule wrightii* is the dominant species followed by *Syringodium filiforme*, *Ruppia maritima* and *Halophila engelmannii*. Funding was provided through NASA Contract NAS10-10285 and Brevard County Environmental Engineering.

9:15 am BIO-25 Evaluating Impacts of Increased Nutrient Loading in Shark River Slough, Everglades National Park (EVER), Florida. DAVID R. WALKER, South Florida Research Center, EVER, Homestead, FL., MARK D. FLORA, National Park Service Water Quality Lab., Fort Collins, CO., RAMONA G. RICE, DWRC, Florida International University, Miami, FL. Proposed water management changes, including the discharge of nutrient rich water from Everglades agricultural areas and water supply back-pumping for the lower east coast, may significantly increase nutrient loading in waters delivered to EVER. To evaluate the possible biological impact of these changes, a two year experimental program was begun by the National Park Service in the freshwater marsh of Shark Slough. Nitrogen as $NaNO_3$ and

Phosphorus as H_3PO_4 are added to simulate maximum allowable concentrations for water entering the park. Three flow-through experimental channels (5m x 100m) are monitored monthly for water quality changes at 10, 20, 35, 65, and 95m downstream from the sources of nutrient addition. Changes in primary productivity are examined through identification and quantification of algal species, 14-Carbon uptake experiments, and biomass as determined by chlorophyll a and dry weight.

9:30 am BIO-26 Preliminary Effects of Nutrient Additions on the Periphyton Community Structure in Shark River Slough, Everglades National Park, Florida. RAMONA G. RICE, Drinking Water Research Center, Florida International University, Miami, Florida, MARK D. FLORA, National Park Service Water Quality Laboratory, Ft. Collins, Colorado, and DAVID R. WALKER, South Florida Research Center, Everglades National Park, Homestead, Florida. Periphyton communities constitute an important component of the freshwater slough systems of the Everglades National Park. Three experimental channels were constructed in the slough with nutrient uptake and periphyton response to nutrient additions measured through biweekly and monthly chemical and by six week periphyton analyses. This paper describes the shifts in periphyton community composition in control and experimental channels from April, 1983 through January, 1984. Periphyton in the control channel is characterized by a Cyanophyta-Bacillariophyta assemblage. Significant changes in the periphyton community composition occurred in the treated channels and these changes are the focus of this paper.

9:45 am BIO-27 An Investigation of Environmental Factors Affecting the Invasion of Schinus terebinthifolius into the Saline Communities of Everglades National Park. LINDA L. MYTINGER, Botany Department, Louisiana State University, Baton Rouge, LA 70803. The integrity of the mangrove communities in Everglades National Park (ENP) is presently threatened by the invasion of a woody Brazilian escapee - Schinus terebinthifolius (Anacardiaceae). Its ability to invade saline communities was underestimated until surveys of the western mangrove fringe of ENP revealed the proliferation of Schinus. This study was designed to investigate the coastal environmental conditions which affect the germination and growth of Schinus, specifically salinity, soil type, and hydrology. Germination of seeds subjected to various methods of scarification was examined as were the effects of salinity on seed viability. Germination and survival of seeds and seedlings planted in various types of coastal habitats under disturbed and undisturbed conditions are compared.

10:00 am BREAK

10:15 am BIO-28 Invertebrate Colonization of Sawgrass and Cattail Leaf Litter During Two Years of Decomposition in the Everglades. NANCY H. URBAN, South Florida Water Management District, P.O. Box V, West Palm Beach, FL 33402. Invertebrates present in sawgrass (Cladium jamaicense) and cattail (Typha domingensis) leaf litter were sampled over a two year period in Everglades Water Conservation Area 2A. Litterbags containing freshly dead leaf material, of either sawgrass or cattail, were placed in the marsh in July, 1981 and were retrieved at regular intervals until July, 1983. Sample sites were located in areas of nutrient enriched water and non-enriched water. Trends in invertebrate populations as affected by plant community and nutrient enrichment were observed.

10:30 am BIO-29 Productivity and Calcification in Four Deep Water Halimeda Species (Chlorophyceae: Caulerpales). P.R. JENSEN*, R.A. GIBSON*, M.M. LITTLER** AND D.S. LITTLER**, *Harbor Branch Foundation, Rt. 1, Box 196, Ft. Pierce 33450 and **Dept. of Botany, N.M.N.H., S.I., Wash. D.C. 20560. Four species of the genus Halimeda were collected off San Salvador Island, the Bahamas, at a depth of 76m using the Johnson-Sea-Link submersible. Samples were incubated at in situ light intensities and temperatures to measure both photosynthetic production and calcification rates.

Photosynthetic rates, measured by O_2 evolution and ^{14}C incorporation, were not significantly different, averaging 0.122 and 0.125 mg C g dry wt.$^{-1}$h^{-1} respectively. These high rates indicate the large potential for organic production by *Halimeda* at light intensities of less than 1% of surface irradiance. Calcification rates, measured by ^{14}C incorporation, averaged 0.088 mg C g dry wt.$^{-1}$h^{-1}. There were no significant interspecific differences between calcification or photosynthetic rates. Calcification rates exhibited a positive relationship with photosynthesis, indicating a biological mediation of the calcification process.

10:45 am BIO-30 Photoadaptation of the Red Tide Dinoflagellare *Ptychodiscus brevis*. EVANNE SHANLEY, Dept. of Marine Science, Univ. of South Florida, St. Petersburg 33701. The ability of *Ptychodiscus brevis* to adapt to changing light regimes may play a major role in the inception and maintenance of red tides in the Gulf of Mexico. Photosynthesis, growth rates, and the time course for adaptation were investigated to elucidate possible photoadaptive strategies of *P. brevis*. Growth rates ranged from .05 doublings/day at 20 μE to an average of .45 doublings/day at 90 μE where growth was saturated. A maximum rate of photosynthesis was found to be 2.094 ± .204 μg C/chl$_a$/hr with an I_k at 120 μE and an initial slope of .02 μg C/chla/hr/ μE for populations previously adapted to 90 μE. Chlorophyll a per cell also varied with light intensity; values ranged from an average of 1.35 x 10^{-5} μg chl$_a$/cell at 20 μE to an average of 1.98 x 10^{-6} μg chl$_a$/cell at 160 μE. It is hypothesized that these photoadaptive responses allow populations of *P. brevis* to maintain maximum growth and photosynthesis rates and thus survive in a turbulent water column.

11:00 am BIO-31 Algal Growth Dynamics of the Suwannee River, Florida, as Determined from Algal Bioassays Using *Selenastrum capricornutum*. LANDON T. ROSS, J. MARSHALL FAIRCLOTH, AND CRAIG W. DYE, Dept. Environ. Reg., 2600 Blair Stone Rd., Tallahassee 32301. Eleven stations along the Suwannee River were sampled 24 times, from Jan., 1982, through Jan., 1984. Algal bioassays were performed on these samples and simultaneous water chemistry data were obtained. Algal growth potential (AGP) was found to increase significantly downstream, although the highest AGP values were found to be directly related to pollution sources. Dilution effects led to lower nutrient concentrations during high flow, and AGP was thus found to be strongly inversely correlated with stage height. Stations along the upper Suwannee often exhibited poor growth responses to nutrient additions, reflecting the unusual water chemistry of the Okefenokee headwaters (extremely soft and acidic), but were generally weakly nitrogen limited. The middle reach of the river was strongly N limited in most cases, due almost certainly to sizeable pollution-generated phosphorus loading. Both P and N limiting conditions were found in the lower river.

11:15 am BIO-32 Growth Rates of Water Hyacinth (*Eichhornia crassipes*) as Influenced by the Nitrogen Concentration of the Growth Media. J. C. TUCKER* AND K. R. REDDY, University of Florida, IFAS-AREC, Box 909, Sanford, FL 32771. Productivity and nutrient uptake of *Eichhornia crassipes* [Mart] Solms were monitored in 1000 ℓ outdoor tanks during the spring of 1983. Nitrogen concentrations of the growth media ranged from <1 mg N ℓ$^{-1}$ to 50 mg N ℓ$^{-1}$. Maximum growth rates (slopes of the linear phase of the growth curve) were obtained when the N concentration of the media was around 8 mg N ℓ$^{-1}$. Nitrogen levels above 8 mg N ℓ$^{-1}$ appear to have little effect on growth. Maximum growth rates obtained ranged from 35 to 45 g dry wt m^{-2} day^{-1}. Rainfall, detritus decomposition and biological N_2 fixation in the root rhizosphere appear to contribute significant amounts of N to plant growth. Additional studies on detritus decomposition has indicated that nutrient release by detritus supported growth rates of up to 17 g dry wt m^{-2} day^{-1}. Shoot lengths and N and P concentrations of the plant tissue were found to be directly proportional to N concentration of the nutrient media.

SATURDAY 9:00 am GCS 118
SESSION E: Environment
E.F. LOWE, St. Johns River Water Management District, presiding

9:00 am BIO-33 Water Quality Trends of Selected Parameters for Coastal Manatee County Florida (1969 - 1983). THOMAS B. LARKIN AND W. J. TIFFANY III, Florida Dept. of Health and Rehabilitative Services, Manatee County Public Health Unit, 202 6th Ave. E., Bradenton, FL 33508. Water quality trends for selected parameters from coastal Manatee County Florida are presented for a fourteen year period (1969 - 1983). Thirteen sample stations located in North Sarasota Bay, Palma Sola Bay, Terra Ceia Bay, the Manatee and Braden Rivers (Mixohaline zone), and South Tampa Bay were sampled monthly. Selected parameters include biochemical oxygen demand (5-day), orthophosphate, nitrate nitrogen, dissolved oxygen, and turbidity. Temporal analysis shows a general reduction in concentration of the selected parameters. Causative mechanisms are discussed.

9:15 am BIO-34 The Assimilative Capacity of Lake Myakka; A Semi-Tropical Eutrophic Lake and Tributary System. B .D. FORTUNE, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. Lake Myakka is a highly disturbed ecological system with excessive nutrient concentrations in the water column and extensive growth of aquatic plants. A one year study of the Lake Myakka system, classified as class 1-A and located within Florida's largest state park, was completed in 1982. The study defines the existing water quality and estimates nutrient loadings to the Lake and flushing rates within the Lake system. Water column data collections, a comprehensive bathymetric survey, algal assays, sediment oxygen demand investigations, plant species identification and numerous mini-studies were performed to determine the assimilative capacity of the system.

9:30 am BIO-35 A Hydrobiological Description of the Green Swamp, a Pivotal Feature of Florida's Environment. P. M. DOORIS, M. LOPEZ, S.W. Fla. Water Mgt. Dist., Brooksville AND G. M. DOORIS, St. Leo College, St. Leo. Covering approximately 870 mi^2 of central Florida, the Green Swamp is of prime biologic and hydrologic importance to the State. The Swamp is dominated by the floodplain forests of the Withlacoochee River, Devil's Creek, and smaller tributaries. Between the riverine systems, the Swamp is a mosaic of flatwoods and cypress ponds interspersed by hammocks and sandhills. Habitats of the Swamp support productive wildlife populations, including those of at least 35 species of rare, endangered, or threatened animals and plants. Two of the State's active Woodstork rookeries are located in the Swamp. A unique hydrologic feature, the Withlacoochee-Hillsborough Overflow, is located in the southwest quarter of the Swamp, and the potentiometric high of the Floridan Aquifer is in the southeast quarter. Pressure for residential, agricultural, and industrial development may compromise the land and water resources of the Green Swamp including those on land now held in public ownership (16% of total area).

9:45 am BIO-36 Pre-Settlement Vegetation of the Upper Withlacoochee River Valley, Central Florida. B. R. WHARTON AND V. J. ATTARDI, S.W. Fla. Water Mgmt. District, 2379 Broad St., Brooksville, FL 33512. As part of the District's environmental assessment of the proposed Green Swamp Flood Detention Area (GSFDA), an analysis of Government Land Office (GLO) survey records is being conducted in an effort to construct a pre-settlement (ca.-1848) vegetation map of the area. Preliminary findings of an analysis of the Withlacoochee River floodplain portion of the GSFDA are presented. Vegetation data from the GLOs were extracted and compared against a current land cover map to identify possible long-term successional trends. The McPherson (1979) Green Swamp area land cover map was converted into a hypothetical original vegetation map, over which the GLO data were superimposed. The data suggest no significant changes in forest composition have occurred; however, there has apparently been a marked expansion of mesic habitats within the upper portions of the floodplain forest, a product of either natural and/or man-induced succession.

10:00 am BREAK

10:15 am BIO-37 The Spatial Pattern of Vegetation on the Floodplain of a Shallow Lake in the Upper St. Johns River Basin, Florida. EDGAR F. LOWE, St. Johns River Water Management District, Box 1429, Palatka 32077. A belt transect of the shoreline of Blue Cypress Lake contained six floristic zones. Proceeding from the water's edge, species most characteristic of these zones were: 1) *Panicum hemitomon* (maidencane), 2) *Eupatorium capillifolium* (dog-fennel), 3) *Ipomoea alba* (moonflower), 4) *Kostelevskya virginica* (seashore mallow), 5) *Osmunda regalis* (royal fern) and 6) *Cladium jamaicense* (sawgrass). Direct gradient analysis suggested that shoreline zonation was the result of a complex gradient in long-term hydrologic conditions. Aerial mapping of vegetation showed that beyond the shoreline, on the marsh flat, the zoned pattern was replaced by a mozaic of communities primarily composed of maidencane wet prairie and dense sawgrass. Fire may have been the major effector of this pattern. Disruption of sawgrass dominance through intense fires on the marsh flat, and perhaps through wave action on the shoreline, may be essential for the maintenance of habitat diversity.

10:30 am BIO-38 Historical changes in the Vegetation of the Upper St. Johns River in Response to Hydroperiod Alteration. GREENVILLE B. HALL and MARVIN M. WILLIAMS, St. Johns River Water Management District, POB 1429, Palatka 32078. The hydroperiod of the floodplain marshes of the upper St. Johns has declined due to significantly lower rainfall (since 1960), and anthropogenic alteration of floodplain drainage and reduction of floodplain acreage. This was probably the primary cause of the alteration of wetland plant communities. To quantify this effect, we used a Geographical Information System (GIS) to digitize vegetation covers of four areas (each 518 ha.) in the marsh. Surface cover types were delineated on the earliest (1943 or 1951) and latest (1980 of 1981) black and white aerial photographs. In localities where annual stage had declined, the areal coverage of woody species (primarily *Salix caroliniana*) increased thereby diminishing the coverage of herbaceaous communities dominated by maidencane (*Panicum hemitomon*) and sawgrass (*Cladium jamaicense*).

10:45 am BIO-39 Preliminary Observations on the Influence of High Ground Water Salinity on the Marsh Flora of Seminole Ranch, Upper St. Johns Basin. GREENVILLE B. HALL and MARVIN M. WILLIAMS, St. Johns River Water Management District, POB 1429, Palatka 32078. During the late Pleistocene, the St. Johns River was probably an inland bay of the Atlantic. Its sediments became infiltrated with salt water, and following a decline in sea level these formed a mesohaline (100-30,000 ppm Cl) artesian aquifer. Geological features exist along the St. Johns which allow the upward movement of this water. Soil water salinities on the Seminole Ranch portion of the basin (1.0 to 37.5 ppt) were consistently one to two orders of magnitude greater than in the surrounding surface waters. Concomitantly, the marshes of this reach of the St. Johns are dominated by salt tolerant and halophytic plant species.

11:00 am BIO-40 Importance of Box Core Penetration and Sieve Size for Macroinfaunal studies on the Southwest Florida Continental Shelf. J.K. CULTER and S. MAHADEVAN, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. Two "typical" soft substrate benthic stations were sampled with a modified Reineck box core sampler (0.045 m^2 surface area) to a depth of 30cm. Five replicate samples from each station were separated into upper and lower 15cm sediment fractions and the macroinfauna retained on a 1.0mm and 0.5mm were identified and enumerated for each fraction. The upper 15cm sediment fractions contained 95% of the total taxa found at both stations. The majority of individuals collected (94% and 96%) were from the upper 15cm, with the relative proportions of taxa and individuals varing only slightly between polychaete and non-polychaete faunal groups. Slightly more than half of the enumerated taxa were retained on the 1.0mm sieve; the majority of individuals were retained by the 0.5mm sieve. The 1.0mm sieve was deemed inadequate for quantitative macroinfaunal studies.

11:15 am BIO-41 Biodegradation of Ethylene Dibromide (EDB) in Lakeland Fine Sand Microcosms. FRANCES PARSONS, GLADYS B. LAGE, AND ERNEST L. DALY, JR., DWRC, Florida International University, Miami, FL 33199. Sealed, static microcosms containing Lakeland fine sand and water were spiked with EDB to give a final concentration of 4ug/L. After eight weeks incubation, gas chromatographic analysis of the water showed the presence of bromoethane. After twelve weeks incubation, the concentration of bromoethane had increased and EDB decreased. Neither ethane nor ethene was detected in the headspace atmosphere created by removal of the water aliquot from the microcosm. Microcosms that yielded bromoethane also yielded bacteria when the contents were cultured. Sterilized microcosms did not yield bromoethane.

COMPUTER SCIENCE AND MATHEMATICS

SATURDAY 8:15 am GCS 202
F.B. BUONI, Florida Institute of Technology, presiding

8:15 am CSM-1 McLaurin Expansions of Elementary Functions. FRED MUNGER, Department of Mathematical Sciences, Florida Institute of Technology. For products of trigonometric and hyperbolic functions such as $\sin^n x \cos^m x$ and $\sinh^n x \cosh^m x$ where n, m are integers (positive or negative) hand calculations of $f^{(j)}(0)$ (the jth. derivative at 0) for large j can become rather tedious owing to the necessity of repeated applications of the product rule and unwieldly summing of large numbers of terms. In this paper a graph-theoretic method is employed which leads to a compact "stacking algorithm," which can be implemented on a computer using integer arithmetic. Exact values for the Euler numbers E_n, which arise in the McLaurin expansion of sec x, are computed up to n = 80 with a CPU time of 2 seconds.

8:30 am CSM-2 Computer Graphics Simulation of Sustained Chemical Oscillations. ROBERT F. STETSON (Florida Atlantic Univeristy, Boca Raton, FL 33431) AND WILLIAM A. HOGAN (Harris Corporation, Computer systems Divsision, Ft. Lauderdale, FL 33310). A computer simulation model which was reported earlier has been adapted to follow chemical oscillations in a two-dimensional drum membrane. The membrane is represented by a two-dimensional circular surface within which an immobilized enzyme is uniformly distributed. The membrane is permeable to two co-substrates, S and A, which diffuse throughout the membrane and exhibit a nonlinear reaction due to the presence of the enzyme. The model follows the spatial and temporal fluctuations of the concentrations of S and A, by illustrating radial and transverse diffusion for both substrates as as function of time. With the proper choice of kinetic parameters, oscillations in the concentrations of S and A develop spontaneously and sustain themselves. For this type of problem an open system is operating far from thermodynamic equilibrium and undergoes an enzyme-catalyzed reaction which is inhibited by an excess of substrate S.

8:45 am CSM-3 The Importance of Speech in Man-Machine Communication. MICHAEL E. VALDEZ, Electrical and Computer Engineering Dept., Florida Institute of Technology, Melbourne, Florida 32901. At the beginning of computer technology man-machine communication was established using whatever resources were available. As technology advances it has become possible to have friendlier communication. Today technoigoy permits interaction by voice in both directions. It is not yet possible to maintain a fluid conversation, but communication is simpler if prompts and acknowledgements are given to the computer by voice instead of printing or display. Similarly the technology exists for command input to the computer by voice. This paper describes the author's system where video display, key strokes, and words intermix to produce a better working environment.

9:00 am CSM-4 Chinese Language Computer Terminal. GEORGE K. KOSTOPOULOS, Professor, Department of Electrical and Computer Engineering, Florida Institute of Technology, Melbourne, Florida 32901. This paper presents the design of a computer terminal for the Chinese language. It employs a character synthesis concept that overcomes the limitation of the Chinese language, and enables the composition of a practically unlimited number of characters. The terminal employs no keyboard, using a light pen for character selection and control. The design is a microprocessor based system with a dual CRT, for separate character selection and character display, both sharing a common character generator.

9:15 am BREAK

9:30 am CSM-5 Intelligent Decision Support. FREDERICK B. BUONI, Florida Institute of Technology, Melbourne, Florida 32901. A paradigm of the decision-making process has been developed which illuminates opportunities for computer-based decision support. Increased use of such decision support is dependent on use of artificial intelligence methods.

9:45 am CSM-6 An Educational Microcomputer Network. M.E. VALDEZ AND M.C. ERTEM, Department of Electrical and Computer Engineering, Florida Institute of Technology, Melbourne 32901. A local microcomputer network was designed and built to expand the capabilities of the AIM 65's in the computer laboratory, to teach computer engineering students about data communications, and as a tool for research. The AIMs did not have mass data storage capabilities, and only provided for hardcopy on a twenty column wide printer. The network made it possible to interface each computer to a central storage device and to a printer. The storage device consisted of four 5.25" disk drives. A star topology was chosen for the network, as this was the simplest to implement. The protocol was also kept simple to allow future expansion by interested students. A master computer was built to operate at the central node of the star topology, and provided the interface to the printer and the disk drives. Such a network is inexpensive, and useful in any computer engineering program.

10:00 am CSM-7 Software Metrics. DR. RAMON A. MATA TOLEDO, Florida Institute of Technology. Computer Science Department, 150 West University Boulevard, Melbourne, FL 32901. Software metrics is a new area in computer science aimed at finding means to evaluate the quality of software programs. A quality program is defined as one that, besides performing to its specifications, is easy to understand, modify, and maintain. The need for a set of tools that can help us in eliminating the factors affecting the quality of software, is economically appealing. Currently, more time is spent maintaining existing software than in developing new code.

SATURDAY 10:15 am GCS 202
BUSINESS MEETING: Computer Science and Mathematics
F.B. BUONI, Florida Institute of Technology, presiding

ENGINEERING

FRIDAY 3:00 pm FLH 318
R.G. BARILE, Florida Institute of Technology, presiding

3:00 pm ENG-1 Solution to Problems in Multidimensional Systems Via Generalized Pade Approximation. Y. SHAMASH AND M. MESSITER, Department of Electrical and Computer Engineering, Florida Atlantic University, Boca Raton, 33431. The field of multidimensional system theory has received a tremendous amount of research interest over the past decade. Areas of application in this field include such topics as image processing, two-dimensional recursive filtering, and seismic data processing. A principal difficulty in the theory of multidimensional systems is the fact that multivariable polynomial with real coefficients cannot always be written as a product of linear factors over C. In this paper we propose solutions to a number of problems in multidimensional systems (the Greatest Common Factor (GCF), Sum and Product Separability, Inverse Systems,...etc.) using a generalization of Pade approximation to multivariable functions.

3:15 pm ENG-2 Decentralized Control Design for Slowly Moving Robot Manipulators. Z. ROTH AND T. C. LAU, Department of Electrical and Computer Engineering, Florida Atlantic University, Boca Raton, 33431. Robot manipulators are characterized by very complicated dynamic equations that incorporate strong coupling among axes. "Slow motion" is defined as the range of required load velocities and accelerations for which centrifugal and Coriolis effects can be neglected. For slowly moving robots the control can be done in a decentralized manner, viewing the varying inertial effects as variations in the mechanical time constants and the varying gravitational effects as variations in the external disturbance on the shaft of each motor. In this paper a step-by-step procedure for writing the simplified dynamic models is developed as well as a systematic control design that takes into account the large variations in system parameters.

3:30 pm ENG-3 VLSI and software-oriented computer architecture. EDUARDO B. FERNANDEZ, Department of Electrical and Computer Engineering, Florida Atlantic University, Boca Raton 33431. Most of the current computers have been designed following principles dictated by technology that existed in the early fifties, a situation where hardware was slow, expensive, and unreliable. Under those circumstances the machine organization had to be very simple, resulting in an instruction set consisting of elementary operations, such as adding two registers or copying the contents of one register into another. This architecture is not very receptive to the software intended to be executed by the machine, and results in unnecessary complexity for the language translators and inefficiency in the execution of program. On the other hand, during the last twenty years many architectural features have been developed in order to make the hardware a more sympathetic vehicle for the execution of software. These architectural extensions are directed to support the execution of programming languages, of the operating system, and of important application-oriented systems such as database management systems.

3:45 pm ENG-4 Chemical Engineering in the Manufacture of Silcon Integrated Circuits. DONALD R. MASON, Florida Institute of Technology, 150 W. University Blvd., Melbourne, 32901. The Electrical behavior and operation of I/C's depend upon the creation of very precise structures on one surface of a carefully prepared wafer of single crystalline silicon having precisely controlled,dilute amounts of additional elements distributed beneath the surface. The surface is protected with a layer of silicon dioxide, over which is a patterned layer of aluminum (for electrical interconnections), which in turn is protected and hermetically sealed with a layer of silicon nitride.

Aspects of cleanliness and contamination control in the manufacturing process will be discussed.

4:00 pm ENG-5 Failures in Integrated Circuits Arising from non-ionic Impurities in pure Water. DONALD R. MASON, Florida Institute of Technology, 150 West University Blvd.,Melbourne 32901. A pseudo-monas bacteria was identified as a contaminant living in deionized water lines made with polyvinyl chloride pipe. Spectroscopic analysis showed that the predominant heavy inorganic elements in this bacterial strain were Fe and Si. Live bacteria can be caught on 0.45 or 0.20 micrometer membrane filters, but nuclei from dead bacteria containing the Fe and Si are not retained by these filters, and can produce water spots on I/C's in the manufacturing process. In a phosphorus diffusion cycle, a eutectic between FeO_x and P_2O_5 can form at 940°C, and between SiO_2 and P_2O_5 at about 975°C. Ternary phase diagram data are not available, but a ternary eutectic below 940°C can be expected.

The formation of a liquid eutectic destroys the effectiveness of the SiO_2 diffusion barrier to P diffusion, and emitter to collector shorts can be formed.

4:15 pm BREAK

4:30 pm ENG-6 The Potential for Air Pollution Problems Resulting from Population Growth in Florida in the Next Decade. N. THOMAS STEPHENS, Department of Environmental Science and Engineering, Florida Institute of Technology, Melbourne, 32901. Projections for a rapid increase in population in Florida over the next few years bring concerns in the environmental community for resultant impacts on air quality. Since man's activities and support system requirements have predictable consequences on air quality, advanced planning to avoid potential problems should be carried out by responsible groups and agencies. In this paper, some of the more serious, and often ignored pollutant generating activities associated with rapid growth are detailed, and suggestions for mitigation measures are made.

4:45 pm ENG-7 Non-circular Free Surfaces and Secondary Flows. MUSERREF WIGGINS, Department of Chemical Engineering, Florida Institute of Technology, Melbourne 32901. The effect of surface tension is studied during melt spinning of the fibers from a rectangular die with no die swell. A model incorporating surface tension is developed. The momentum and continuity equations for steady isothermal spinning of Newtonian and power-law fluids are solved using finite difference techniques. Planar and axial velocity profiles are obtained. With all fluids a secondary flow recirculation cell was observed. Surface tension tends to deform the cross-section toward more circular shapes, which is in accordance with theory. When surface tension forces are neglected, the extrudate remains rectangular with both rheological models. The secondary flow recirculation cells are displaced toward the center of the fiber along the flow direction under the effect of surface tension.

5:00 pm ENG-8 Economics of a New Biomass Automobile Fuel: Angelica Lactone, RONALD G. BARILE AND JOHN THOMAS. Florida Institute of Technology, Chemical Engineering and Medical Research Institute, Melbourne, 32901. Angelica lactone, C H O , is a ring compound in the furan family. It has superior fuel qualities in internal combustion engines and can be mixed with gasoline up to 40% by volume. Virtually any cellulosic biomass can be hydrolyzed in acid under mild pressure and temperature to produce an intermediate, levulinic acid, which is then reacted in vacuum to produce pure angelica lactone (AL) vapor. Mass yields are on the order of 50%. Economic studies show that the cost of energy input as process heat (distillation and reaction) controls the selling price of AL, as well as the amount of internal process energy recycle. Thus, wood and bagasse are particularly attractive as raw materials, especially in a rural setting where biomass is already collected. Formic acid and solid fuel are significant coproducts which also impact heavily on the price, ranging from $1.00 to $4.00 per gallon.

5:15 pm ENG-9 Description of a General CAD 2-D Menu. B.H. THRASHER, Ph.D., P.E., Mechanical Engineering Department, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. This presentation describes the Variable Two Dimensional Menu (VTDM^{TM}) developed for the IHS-CAD (and TQ-CAD) computer aided design systems. IHS-CAD is a microcomputer based three dimensional computer aided design system used to generate engineering drawings by computer. VTDM is a computer subroutine which controls a menu of two dimensional subelements (or primatives). These primatives are totally definable by the user and stored at appropriate locations on the menu. These are recalled to aid in the generation of the final drawing.

FRIDAY 5:30 pm FLH 318
BUSINESS MEETING: Engineering
R.G. BARILE, Florida Institute of Technology, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

ENVIRONMENTAL CHEMISTRY

FRIDAY 8:45 am GCS 203
SESSION A: Techniques
F.E. DAVIS, South Florida Water Management District, presiding

8:45 am ENV-1 Development of the Nutrient Film Technique as an Alternative Process to Treat Secondary Effluent for Nonpotable Reuse. JOSE LUIS LOPEZ, WILLIAM COOPER, DR. LINDA HANDLEY AND LEE CASEY, Florida International University, Drinking Water Research Center, Tamiami Campus, Miami, FL 33199. The Nutrient Film Technique is a modification of hydroponic plant culture which optimizes the contact between plant roots and nutrients. A thin film of water flowing through the extensive root system also provides a habitat suitable for microbial growth. Plants, growing on an impermeable surface, are used as a chemical and physical filter to remove the gross and trace chemicals in wastewater. The assimilated nutrients can be removed by harvesting the plants. Based on the natural capability of plant roots for removing chemicals from water and the minimal outside energy required for support and maintenance, it seems that in the field of low cost treatment, the Nutrient Film Technique could be one solution for wastewater treatment/reuse. Preliminary design criteria for pilot scale Nutrient Film reactors and the feasibility of this technique are discusssed.

9:00 am ENV-2 Inapplicability of a Nitrate Ion Selective Electrode for Routine Monitoring of Water Backpumped into Lake Okeechobee. MARY LOU DANIEL, South Florida Water Management District, P.O. Box V, West Palm Beach, FL 33402. During the summer of 1982 the District backpumped water from the agricultural area south of Lake Okeechobee into the lake to partially mitigate the effects of the drought. This water contained significant quantities of nitrate which required daily monitoring during pumping. In order to meet the need for rapid results, attempts were made to utilize a nitrate ion selective electrode as a field monitoring procedure. Due to the interference of chloride (>100 mg/L) the procedure did not give acceptable results in the nitrate concentration range (0.5 - 10.0 mg/L) encountered in this study. Several ionic strength adjustment buffers, precipitation of the chloride and filtration were tried. However, the results were not acceptable when compared to the results obtained by the automated cadmium reduction-diazotization method.

9:15 am ENV-3 Use of Coupled Columns for the Capillary Gas Chromatographic Separation of Water Pollutants. MEHRZAD MEHRAN AND W. COOPER, Drinking Water Research Center, Florida International University, Miami, Fl 33199, AND W. JENNINGS, Department of Food Science and Technology, University of California, Davis, CA. 95616. Determination of specific chemical pollutants in water requires their unambiguous separation; because of the large number of samples that require attention, analysis times become critically important to screening laboratories. Both of these considerations imply that the use of capillary, or open tubular columns, should offer a superior gas chromatographic approach. Using computer-predicted lengths of columns coated with dissimilar stationary phases, a coupled capillary column was constructed, which resolved a mixture of 18 halogenated compounds with an analysis time of 13 minutes. The approach and implications will be discussed.

9:30 am ENV-4 Determination of Glyphosate Herbicide in Environmental Samples. CARL J. MILES AND H.A. MOYE, University of Florida, Department of Environmental Engineering Sciences and Pesticides Research Lab, Department of Food Science and Human Nutrition, IFAS, Gainesville, Florida 32611. Glyphosate (N-phosphonomethyl glycine) is a broad spectrum, nonselective, postemergence herbicide that has found widespread agriculture and domestic use. Because of its low mammalian toxicity and subsequent low risk of environmental pollution, analytical methods for determination of glyphosate in environmental samples has not been avidly pursued. Nevertheless, the effect of glyphosate on non-target organisms cannot be fully eveluated unless suitable techniques are available. We have investigated two analytical methods for the determination of glyphosate and its major metabolite, aminomethylphosphonic acid, in water, vegetation and soil. These methods employ HPLC with post-column and pre-column fluorogenic labeling. Analytical conditions, sample preparation, and recovery studies will be discussed.

FRIDAY 10:00 am GCS 203
SESSION B: Contaminants
F.E. DAVIS, South Florida Water Management District, presiding

10:00 am ENV-5 Oil Pollution in Florida Estuaries. RICHARD H. PIERCE, ROBERT C. BROWN, and JOHN R. KUCKLICK, Mote Marine Laboratory, 1600 City Island Park, Sarasota, FL 33577. EDWARD S. VAN VLEET, University of South Florida, Department of Marine Science, 140 Seventh Ave. South, St. Petersburg, FL 33701. The distribution of hydrocarbons was investigated in Charlotte Harbor, the lower Hillsborough River and in Tampa Bay Florida. Hydrocarbon patterns were characterized by high resolution gas chromatography and mass spectroscopy to identify major sources of petroleum contamination and to establish background biogenic hydrocarbons. These studies identify oil pollution from specific land and water use activities and provide baseline information for oil contamination throughout Charlotte Harbor and parts of Tampa Bay.

10:15 am ENV-6 Analysis of an Existing Urban Stormwater Management System in South Florida. MICHAEL CULLUM, S. Fl. Water Man. Dist., P.O. Box V, W. Palm Beach, 33402. The SFWMD currently enforces a "one inch rule", which requires on-site detention for the first inch of runoff from developed areas. This rule has provided attenuation of elevated stormwater flood peaks due to increased urban development within the District. The added benefit of water quality treatment has gone largely unresearched in the south Florida area. Timbercreek subdivision, contains 114 acres of single family homes along with eight acres of detention ponds. This site was monitored for water quality and hydrologic data for 1½ years. In this period, nine discrete storm events were documented. Preliminary results indicate an average difference in pond influent and effluent concentrations of 70% for nutrients and 77% for suspended solids. Further analysis of the system on a mass loading basis should enhance these results. The conclusions from Timbercreek, along with those from other sites, will be used to develop a representative strategy for protecting south Florida's receiving waters from non-point source stormwater pollution.

10:30 am ENV-7 Hydrolysis and Degradation of Aldicarb in Groundwaters From Citrus Groves in Indian River County. CHRIS J. GIVEN AND FORREST E. DIERBERG, Dept. of Environmental Science and Engineering, Florida Institute of Technology, Melbourne 32901. The pesticide aldicarb (2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime) was spiked in pH 4,6,7,8, and 9 buffered distilled water. After 89 days there were no changes at pH 6,7, and 8 in the aldicarb and its oxides from the initial concentrations. At pH 4, the concentration decreased to 65% of the amount added; 27% of the amended aldicarb remained after 89 days in the pH 9 buffer. Sterile and unsterile groundwaters from 3 shallow (55 to 66 ft) wells (pH 6.8 to 7.3) spiked with aldicarb showed no degradation after 5 days. Standard plate counts for anaerobic bacteria in the groundwater ranged from 2 to 50 cells/mL.

10:45 am ENV-8 Dihaloacetonitriles in Chlorinated Natural Waters. THEODORE I. BIEBER AND MICHAEL L. TREHY, Department of Chemistry, Florida Atlantic University, Boca Raton 33431. In this paper a review is presented of our findings on the occurrence of dihaloacetonitriles in drinking water. These contaminants are a direct result of the chlorination of natural waters. The reaction of chlorine with nitrogen-containing substrates normally present in natural waters, principally proteins, is responsible for dihaloacetonitrile formation. A number of important aspects, such as analysis, half-lives and health effects, will be touched upon.

11:00 am ENV-9 A Predictive Kinetic Model of Trihalomethanes (THMs) in Chlorinated Groundwater. L.S. CASEY, W.J. COOPER AND R.J. CLOUD, Florida International Univ. Drinking Water Res. Ctr., Miami 33199. It is well established that THMs in drinking water are a byproduct of chlorine disinfection. A method to predict the distribution and concentration of THMs is important because of health risks associated with chronic exposure to these compounds. A literature review has provided information on the chemistry of water chlorination and reaction rates. The reactions are described by a set of simultaneous differential equations which forms the basis of the model. Numerical solution of these equations yields an estimate of the distribution and concentration of the four THMs commonly found in drinking water. The model was designed to use pH, temperature, chlorine dose, contact time, bromide, ammonia and total organic carbon as major input variables and was calibrated against laboratory experiments designed to identify the influence of these variables. The predictive capacities and use of the model to minimize the amounts of THMs formed are discussed.

11:15 am DISCUSSION, with Introductory Comments on "Hazardous Waste-
It's Management and Risk in Florida", by W. LAMAR MILLER,
University of Florida.

FRIDAY 11:45 am GCS 203
BUSINESS MEETING: Environmental Chemistry
F.E. DAVIS, South Florida Water Management District, presiding

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

FRIDAY 3:00 pm GCS 203
SESSION C: Wetlands and Lakes
F.E. DAVIS, South Florida Water Management District, presiding

3:00 pm ENV-10 Nitrogen Transformations in Wetlands Receiving Primary Sewage Effluent. W. F. DEBUSK AND K. R. REDDY, University of Florida, IFAS-AREC, Box 909, Sanford, FL 32771. Primary sewage effluent spiked with labelled ammonium-N was added to wetland microcosms in order to determine the fate of nitrogen in primary sewage effluent applied to a cypress-mixed hardwood swamp. Over 98% of applied ^{15}N was removed from floodwaters within the 21-day incubation period. Nearly all of the ^{15}N remaining in the water was present as nitrate-N. Approximately 15% of applied ^{15}N was recovered in the sediment, with a substantial portion of that immobilized in the litter layer by microbial assimilatory reduction. Other nitrogen-related processes occurring near the sediment-water interface were diffusion, nitrification-denitrification, adsorption and desorption of ammonium-N, and mineralization of organic N. Mass balance showed about 85% of applied ^{15}N unaccounted for, presumably lost through ammonia volatilization and nitrification-denitrification.

3:15 pm ENV-11 Trophic Nature of Selected Urban Lakes in Florida. FORREST E. DIERBERG AND PATRICK L. BREZONIK, Dept. of Environmental Science and Engineering, Florida Institute of Technology,Melbourne, FL 32901, and Dept. of Civil and Mineral Engineering, University of Minnesota, Minneapolis, MN 55455. A limnological survey of 30 lakes located in 4 urban areas in central and south Florida was conducted during the summer of 1981. The best estimate for urban lake chlorophyll a and Secchi disk depths were obtained from previously published empirical models, thus widening the scope of their applicability to infrequently sampled lakes surrounded by urban watersheds. Phosphorus was the common limiting nutrient, causing varying degrees of productivity among the lakes as they are grouped according to population centers. Using an average trophic state index based on the subindexes of Secchi disk, chlorophyll a, total phosphorus and total nitrogen, sixty percent of the sampled lakes were either eutrophic or hypereutrophic; thirty percent were oligotrophic and only ten percent were mesotrophic. Eutrophic and hypereutrophic conditions were common to the Orlando and Lakeland-Winter Park lakes, making them likely candidates for restoration.

3:30 pm ENV-12 Groundwater Seepage in East Lake Tohopekaliga. THOMAS V. BELANGER AND DONALD F. MIKUTEL, Department of Env. Science, Florida Institute of Technology, Melbourne, FL 32901. The direct seepage measurement technique was applied to East Lake Toho to determine the importance of seepage to the water and nutrient budgets of the lake. The study revealed that seepage in this lake contributed approximately 14 percent of the total inflow to the lake and nine and 18 percent of the total phosphorus and nitrogen loads, respectively, during 1983. Nutrient loading was estimated with piezometer data, as seepage meter concentration data were felt to be elevated due to anaerobic conditions in the enclosures.

3:45 pm ENV-13 Lake Profiles by Ground Penetrating Radar for the Meginnis Arm Restoration Project in Lake Jackson. SHIOU-SAN KUO, Dept. of Civil Engineering & Environmental Sciences, University of Central Florida, Orlando, FL. 32816. ERIC LIVINGSTON, Florida Dept. of Environmental Regulation, Tallahasse, FL. Before proposing any strategy for the restoration of Meginnis Arm in Lake Jackson, Tallahassee, it was necessary to map the lake bottom profiles and determine the bottom sediment deposits. Normally, the lake bottom profiles are obtained by sample corings at spacings necessary to define adequately the area being surveyed. Such work is highly labor intensive and relatively slow. The lake profiles mapped by ground penetrating radar proved to be a quicker, less expensive, and much more accurate method compared to other methods such as sample corings or sound device fathometer techniques.

4:00 pm ENV-14 An Investigation into the Importance of Sediment Nutrient Exchange on Algal Productivity in Meginnis Arm of Lake Jackson. HARVEY H. HARPER, III, and MARTIN P. WANIELISTA, Civil Eng. and Env. Sciences Dept., Univ. of Central FL. Orlando 32816. ERIC LIVINGSTON, FL Dept. of Env. Reg., Tallahassee. To investigate the relationship between sediments and water nutrient concentrations in Meginnis Arm of Lake Jackson, a series of in situ isolation chambers were established. Each chamber, covered an area of $0.75\ m^2$ and isolated approximately 1000 L of water. Various methods of sediment inactivation were used including alum, alum sludge, and complete dredging. One chamber received no additions, and one chamber was isolated from sediment exchange with plastic film. It was shown that the sediments in Meginnis Arm contribute significatly to the nutrient budget of the overlying waters and that this nutrient input result in increases in algal production and average dissolved oxygen concentrations. Both alum sludge and alum prevented nutrient releases. The dredging processes increase nutrient concentrations considerably for a period of several weeks followed by a decline to near initial value.

GEOLOGY AND HYDROLOGY

FRIDAY 9:00 am GCS 238
C.J. MOTT, St. Petersburg Junior College, presiding

9:00 am GHY-1 Rainfall and Surface Water Deficits in the Upper St. Johns River Basin, Florida. EDGAR F. LOWE and LAWRENCE R. GERRY, St. Johns River Water Management District, POB 1429, Palatka, 32078-1429. Low water level in the floodplain marsh was probably the primary cause of recent reductions in the populations of fish and waterfowl and alteration of the distributions of wetland plant communities. Although rainfall in recent years (1960-1982) has been significantly lower than in previous years (1931-1959), other work indicated that anthropogenic alteration of floodplain drainage and reduction of floodplain acreage may have intensified the surface water deficit. Regression analysis indicates a significant change in the relationship between total annual rainfall and annual mean surface water elevation occurred in the mid-1950s. The analysis suggests that the rainfall deficit was insufficient to have caused the decline in mean surface water elevation (0.74 m) and that in the absence of extensive floodplain alterations mean elevation would have changed very little.

9:15 am GHY-2 Water Quality of the Floridan Aquifer System, Kissimmee Planning Area. JONATHAN E. SHAW, South Florida Water Management District, P. O. Box V, W. Palm Beach, FL 33402. The Kissimmee Planning Area (KPA) of the South Florida Water Management District (SFWMD) encompasses an area of approximately 3500 square miles, and extends from Orlando to Okeechobee. The Floridan Aquifer System is the primary source of drinking water in the northern portion of the KPA, and a major source of agricultural water supply throughout the KPA. The water quality of the Floridan Aquifer System is highly variable. As ground water moves down gradient, the dominant ions change and the overall ionic concentration increases. Ground water in the recharge area, to the northwest, is a calcium bicarbonate type. Ground water traveling to the southeast becomes a transitional type, and finally a sodium chloride type at the down gradient extent. Four different methods of ground water quality interpretation were used; contour mapping of raw data, Stiff patterns, Piper Trilinear diagrams and factor analysis. The Piper Trilinear diagram furnished the best representation of regional groundwater trends.

9:30 am GHY-3 Ground-Water Contamination by Synthetic Organics and Petrochemicals. TIMOTHY C. VARNEY, Central Florida Regional Planning Council, P.O. Box 2089, Bartow 33830. In recent years the incidence and identification of ground-water contamination by synthetic organic compounds and petrochemicals has been increasing at an alarming rate. Where both of these contaminant categories are concerned, the halogenated solvents and fugitive gasoline from perforated tanks lead the list in most effected areas. Of primary concern are the dificulties associated with sampling and accurately identifying these compounds in ground-water, available methods for treatment and cleanup, safety of field personnel and general environmental health considerations. The purpose of this paper is to speak to the preceeding concerns with direct reference to actual field cases and alternative methods for monitoring and control.

9:45 am BREAK

10:00 am GHY-4 Beach Profile Response after Beach Nourishment at Selected Projects in Florida and New Jersey. JEFFREY HOEL AND DONALD K. STAUBLE, Florida Institute of Technology, Dept. of Oceanography and Ocean Engineering, Melbourne, Fl. 32901. The high cost of project regulation and implementation and dwindling sources of public funding has lead to a need to develop guidelines for performance monitoring of beach restoration and inlet sand transfer projects. Beach profile data collected before, immediatily after and at specific intervals throughout the project monitoring period are important in understanding the behavior of the fill. By collecting a history of elevation changes from several recent projects in Florida and New Jersey, information was obtained on the state of the pre-nourished beach, volume of fill placed along the project, areas of erosion and accretion of the fill after placement and assessment of long term need to renourish the project beach. Computer analysis of profile response from this field data has lead to an understanding of how artificial fill responds to natural coastal processes.

10:15 am GHY-5 Temporal and Spatial Variations of Sediment Textural Characteristics at Several Beach Nourishment Projects in Florida and New Jersey. WADE J. BLAKE AND DONALD K. STAUBLE, Florida Institute of Technology, Dept. of Oceanography and Ocean Engineering, Melbourne, FL 32901. The high cost of beach nourishment projects requires that we be able to predict how fill placed on a beach will respond to coastal processes. An analysis of sediment textural data from several beach nourishment projects in Florida and New Jersey was done to understand the behavior of borrow material placed as beach fill. Investigations into sediment sampling technique and analysis provided insight into the samples which best represent fill response. Computer generated frequency distribution curves, histograms and probability plots were used to interpret changes in the grain size distributions. From this analysis, guidelines can be drawn up for the selection of suitable borrow material and for improvement in physical monitoring of future beach nourishment projects.

10:30 am GHY-6 Mechanisms of Notch Formation along the South Haitian Coast. DONALD W. LOVEJOY, Palm Beach Atlantic College, 1101 South Olive Avenue, West Palm Beach 33401. Intertidal erosion affects Haiti's lime-rich rocks in a low energy, microtidal tropical environment. Erosional features known as "notches" are conspicuously present at the base of many sea cliffs. Possible explanations for the origin of these notches are (1) wave abrasion, (2) weaknesses due to rock stratification, (3) pressures set up by growth of salt crystals upon drying, (4) dissolving of the rock by rainwater, salt spray, seawater, or groundwater emerging at the base of the cliffs, and (5) biological erosion. Evidence suggests that biological erosion is the most important factor. Principal organisms involved are browsing gastropods, algae, and rock boring echinoids. The following zonation can be recognized: (1) upper zone: raindrop/spray pitted with *Littorina* spp., *Tectarius muricatus*, and *Nerita tessellata*, (2) middle zone: *Acanthopleura granulata* and a crustose coralline alga, and (3) lower zone: *Echinometra lucunter* and green algae.

10:45 am GHY-7 A Statistical Test of Lester King's Hillslope Model in the Pacific Mountain System of North America. ROBERT O. CLARK, Department of Geography, University of South Florida, Tampa, FL 33620. Lester C. King, the South African Geomorphologist, has long contended that most climatic regimes irrespective of their terrain and lithology develop a general homology of landform types with distinctive multiple-element profiles. To test the validity of this hypothesis, sample populations of slopes were selected at random from areas in the Pacific Mountain System. A multiple-element curve depicting the King model was then mathematically fitted to each set of hillslope axes in the total sample. By statistically comparing actual and theoretical declivities in a test area, regression equations were developed to predict slope angles in other areas of the province. A statistical analysis of mean deviations between actual and predicted slope angles and the determination of percentage variances from a comparison of actual and predicted profiles demonstrated a general inadequacy of the multiple-element curve as a representative model of geomorphic evolution, at least for the Pacific Mountain System.

FRIDAY 11:00 am GCS 238
BUSINESS MEETING: Geology and Hydrology
C.J. MOTT, St. Petersburg Junior College, presiding

MEDICAL SCIENCES

FRIDAY 9:00 am GCS 115
SYMPOSIUM: Acquired Immunodeficiency Disease Syndrome, "AIDS".
C. MACLEOD, University of Miami, presiding

Speakers and topics to be announced in a Program Supplement available at the Registration Desk and Symposium.

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

FRIDAY 3:00 pm GCS 204
A.C. VICKERY, University of South Florida, presiding

3:00 pm MED-1 A Monoclonal Antibody Coagglutination (COA) Confirmation Test for *N. gonorrhoeae*. DENO KAZANIS, PHILLIP AMUSO AND JACK W. FRANKEL, Tampa Branch Laboratory, P.O. Box 2380, Tampa 33601. We investigated a monoclonal antibody coagglutination test (Gono Gen, Micromedia) on the basis of its use as a routine clinical laboratory test for confirmation of presence of *N. gonorrhoeae*. This test is based on agglutination of positive gonococcal specimens by a pool of murine monoclonal antibodies directed against protein I (principle outer membrane protein) of *N. gonorrhoeae* that have been absorbed to Cowan I strain of *Staphylococcus aureus*. Over 10,000 routine specimens, submitted on Martin-Lewis medium, were screened for presence of *N. gonorrhoeae*. Of these, 408 were found to have colonies positive for *N. gonorrhoeae* in presumptive tests (Gram stain and oxidase test). We then compared the monoclonal antibody COA test with the standard sugar utilization technique. This COA test provided a 98.5% confirmation and proved superior to the sugar utilization technique on the basis of speed of results (15 minutes), ability to confirm autolyzed cells and detection of *N. gonorrhoeae* in mixed cultures.

3:15 pm MED-2 Diethylcarbamazine (DEC) Mediated Clearance of *Brugia pahangi* Microfilariae in Nude Mice. ANN C. VICKERY AND MARK TAMPLIN, University of South Florida, College of Public Health, 13301 N. 30th Street, MHC 6-238, Tampa, Florida 33612. Congenitally athymic nude C$_3$H/HeN mice infected with *B. pahangi* exhibit a peripheral microfilaremia approximately two months after inoculation (SC) with 50 infective larvae. Although microfilaremias fluctuate and absolute numbers of microfilariae (mf) vary between individual mice, the tendency is for numbers of mf to increase with time. A single treatment of infected nudes with DEC (100 mg/kg body weight, *per os*) rapidly clears mf from the circulation so that by three hours after treatment, numbers of mf are significantly reduced ($P < 0.005$). Neither thymus grafting, which allows infected nudes to mount immune responses specific for parasite antigens, nor cobra venom factor depletion of complement, has an effect upon microfilarial clearance by DEC. These results suggest a non-immune, complement independent mechanism of action for DEC.

3:30 pm MED-3 Characterization of Cellular Infiltrates Following Intratracheal Inoculation with *Histoplasma capsulatum*. RANDALL M. SUMNER and DEBORAH A. NICKERSON, Department of Biology, University of South Florida, Tampa, FL 33620. Murine pulmonary responses to live or heat-killed (HK) yeast cells from the dimorphic fungus, *Histoplasma capsulatum*, have been characterized in C57Bl/6 mice. Two to five-fold increases in total lung and tracheobrachial (tb) lymph node cellularity were noted 48 hr following immunization with either live or HK yeast cells. In contrast, the number and composition of splenic or mesenteric lymph node cells remained well within control (normal) values over the course of study (35 days). The total number of immune cells found in lungs or tb lymph node returned to control levels 14 or 28 days following inoculation with HK or live yeast cells, respectively. Substantial elevations of T lymphocyte and macrophage subpopulations were noted in these cellular infiltrates. Supported by USPHS research grant AI-11750.

3:45 pm MED-4 Induction of Murine Lymphocyte Blastogenesis by *Histoplasma capsulatum*. LORRIE FRIEDRICH and DEBORAH A. NICKERSON, Department of Biology, University of South Florida, Tampa, FL 33620. *In vitro* blastogenic responses by normal murine splenocytes have been detected following exposure to heat-killed (HK) yeast cells of *Histoplasma capsulatum*. HK yeast cells induced ten to twenty-fold increases in ^{3}H-thymidine uptake by spleen cells from Balb/c mice. Optimal lymphocyte mitogenesis was stimulated three days following culture initiation. Blastogenesis was also stimulated with spleen cells from several other mouse strains, i.e. C3H/HeJ and C57BL/6J. Finally, mitogenic activity was also associated with soluble yeast cell autolysates. Preliminary characterization of the lymphoid cell subpopulation(s) stimulated by *H. capsulatum* are currently underway. Supported by USPHS research grant AI-11750.

4:00 pm MED-5 Testosterone-Induced Sex Reversal in the Volume of the Sexually Dimorphic Nucleus in the Anterior Hypothalamus of the Mouse Brain. Peter Mouton and G. Arendash, Dept. of Biology, University of South Florida, Tampa, FL 33620. We have recently demonstrated the existence of a Sexually Dimorphic Nucleus in the Anterior Hypothalamic Area (SDN-AHA) of the mouse brain wherein the volume of an area characterized by increased neuronal density is 70% larger in males than in females. The present study was conducted to determine if the development of the SDH-AHA is dependent on the sex hormone environment of the mouse brain during the critical perinatal period of sexual differentiation. Neonatal females of the ICR strain were given daily, subcutaneous injections of 40ug testosterone (TP; a male sex hormone) during the first 7 days after birth. After all animals had been allowed to attain adulthood, a microscopic analysis of SDN-AHA volumes indicated that SDN-AHA volumes of TP-treated females (i.e., hormonally masculinized) were the same as those of oil-treated males ($p<.0001$), and were dramatically greater than SDN-AHA nuclear volumes of oil-treated females ($p<.0001$). Thus, a complete sex reversal of the SDN-AHA is possible.

4:15 pm MED-6 Feasibility Study of a Diagnostic Test to Identify Individuals at Risk for Cancer. JACK W. FRANKEL, PASCUAL BIDOT AND HARVEY SAMIS, Tampa Branch Laboratory, P.O. Box 2380, Tampa 33601 and VA Medical Center, Bay Pines 33504. An in vitro viral transformation assay is being assessed as a diagnostic index to identify individuals at risk for lung cancer and neurofibromatosis (NF), an autosomal disorder characterized by formation of multiple skin tumors. The studies reveal significant differences in transformability of skin fibroblasts (SF) established from cancer and control groups by Kirsten murine sarcoma virus. Seventy seven of 90 SF cultures (86%) from lung cancer patients are transformed, compared with 4 of 107 (<1%) cultures from normal age-matched controls (P=<0.001). SF from 73% of patients with clinically apparent NF are transformed, as are SF from 81% of asymptomatic first degree relatives of patients with the disease. None of 39 SF from NF free families are positive. The assay presents a prenatal counseling tool for NF, representative of disorders most difficult to diagnose due to high genetic frequency and variability of expression.

4:30 pm MED-7 Needs Assessment of Cuban and Haitian Refugees in Tampa. CHRISTINE R. GEISER AND E. LEE HUSTING, University of South Florida, College of Public Health, 13301 N. 30th Street, MHC 6-238, Tampa, FL 33612. A needs assessment of Cuban and Haitian refugees in Tampa was performed for the purpose of assisting Catholic Social Services, Tampa, in planning a new refugee home management program. Data documenting the needs of Cuban and Haitian refugees in Tampa was obtained by using a descriptive survey methodology consisting of nine key informant interviews, and a survey questionnaire mailed to fifty-seven community members who have been involved with refugee resettlement. Forty-one (seventy-two percent) of the fifty-seven respondents completed the questionnaire from which a ranking of refugee home management needs was derived. Finding jobs, learning English, and medical care were the top-ranked needs. Recommendations for the refugee home management program are presented.

4:45 pm MED-8 Employment of a Balloon Hemodynamic Model in Generating Pressure Waveforms Similar to Those Seen During Bedside Hemodynamic Monitoring--A Comparative Study. CHARLES J. GUTIERREZ, L. TIMOTHY WORRELL AND LOUIS J. ACIERNO, Cardiopulmonary Research Lab, Respiratory Therapy Program, University of Central Florida, Orlando, Fl 32816. A longitudinal, commercially available balloon was employed as a hemodynamic model for the purpose of generating pressure waveforms similar to those measured in the heart and lungs. When manipulated in specific ways, the fluid filled balloon, in conjunction with a Swan-Ganz catheter, transducer and an E for M polygraph produced recordings of pressure waveforms similar to those characteristically found in the heart's right atrium, right ventricle, pulmonary artery and pulmonary capillary bed. A qualitative comparison of waves generated in the laboratory with those obtained from patients undergoing bedside hemodynamic monitoring revealed sufficient correlation in terms of fidelity and reproducibility to possibly warrant usage of the balloon hemodynamic model as a tool in teaching the clinical application of the Swan-Ganz catheter.

FRIDAY 5:00 pm GCS 204
BUSINESS MEETING: Medical Sciences
D.A. NICKERSON, University of South Florida, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

PHYSICAL AND SPACE SCIENCES

FRIDAY 8:30 am GCS 208
R. BONE, Florida International University, presiding

8:30 am PSS-1 Raman Spectrum of Solid Ammonia. C. L. NYE AND F. D. MEDINA, Physics Department, Florida Atlantic University, Boca Raton, 33431. Polycrystalline samples of phase I of solid ammonia have been grown from the liquid phase at several points on the melting line. Raman spectra of these samples have been recorded. The observed temperature and volume dependences of the Raman frequencies and linewidths will be discussed.

8:45 am PSS-2 Spin Waves in Static Magnetic Structures. J.D. Patterson, Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901. Reflection and transmission coefficients are calculated for spin waves incident on magnetic domain walls in a variety of geometrical situations. These include spin waves incident on Bloch and Néel walls. A very important parameter to consider is the ratio of the wave length of the spin waves to the width of the wall. In general when this parameter is small the spin waves are easily transmitted. Permanent address: Physics Department, South Dakota School of Mines and Technology, Rapid City.

9:00 am PSS-3 An Analysis of Light Coupling into Thin Film Dielectric Optical Waveguides. E. F. Strother, Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901. A review of some of the important electro-optical developments in integrated optical devices is given. Emphasis is placed on the properties of thin dielectric films which are used as waveguides at optical frequencies. An analysis for determining the allowed propagation modes of guided waves in a slab waveguide is developed from Maxwell's Electromagnetic Field Equations and the dispersion relationship for propagation modes in these waveguides is derived. Attenuation and power densities in the guide are estimated and a numerical example is given for a typical case in which YAG:Nd laser light ($\lambda = 1.06\,\mu$m) is confined to a ZnS thin film waveguide ($n_f = 2.2899$). The characteristics of the prism coupler as a mode launching device are analyzed and a technique for calculating the efficiency of coupling light into a thin film optical waveguide is presented. Also discussed are the coupling techniques involving gratings and tapered films.

9:15 am PSS-4 Nuclear Form Factors in the Time-Like Region. S.L. MINTZ Physical Sciences Department, Florida International University, Miami, Florida 33199. Weak Processes in nuclei are described in terms of form factors. Gauge invariance is then used to obtain the form factors in the time-like region. The experimental consequences of the results are examined.

9:30 am PSS-5 Neutral and Charged Charged Inclusive Neutrino Reactions in ^{12}C and the pion-Electroproduction Cross Section. S.L. Mintz and D.F. King, Department of Physical Sciences, Florida International University, Tamiami Trail, Miami, FL 33199. Total muon capture rates and inclusive pion electroproduction cross sections in ^{12}C. These results are obtained for 150 Mev$\leq E_{\nu} \leq$ 250 Mev for the charged current case and 50 Mev$\leq E_{\nu} \leq$150 Mev for the neutral current case. Comparison is made with other calculations.

9:45 am PSS-6 "Vacuum Ultraviolet Natural and Magnetic Circular Dichroism Measurements with Synchrotron Radiation", Patricia Ann Snyder, Chemistry Department Florida Atlantic University, Boca Raton. Synchrotron Radiation from modern electron storage rings is highly linearly polarized, a continuum, collimated, and more intense than conventional vacuum ultraviolet sources. These attributes are ideal for natural and magnetic circular dichroism measurements in the experimentally difficult vacuum ultraviolet region. The first vacuum ultraviolet natural and magnetic circular dichroism experiments using synchrotron radiation have been carried out on Pantulus I at the Synchrotron Radiation Center, University of Wisconsin, Madison. The natural and magnetic circular dichroism instruments, which have been constructed, will be presented. In addition, spectra which illustrate the capability of the instrument and usefulness of these techniques will be presented. Acknowledgements: This work was supported by the NSF under grants CHE 8108534 and DMR 7721888, by the Research Corporation and by the Division of Sponsored Research of Florida Atlantic University.

10:00 am BREAK

10:15 am PSS-7 The Gravitational Collapse Of The Cores Of Massive Stars And Its Relationship To Type II Supernovae. STEPHEN W. BRUENN, Physics Dept., Florida Atlantic University, Boca Raton, FL 33431. The collapse of the cores of massive stars evolved from the main sequence by Weaver and Woosley were followed numerically. General Relativistic hydrodynamics was used to evolve the matter, and a multigroup, flux-limited diffusion scheme was used to independently evolve ν_e's, $\bar{\nu}_e$'s, and ν_μ and ν_τ pairs. Particular care was taken to compute the deleptonization of the core accurately. The results indicate that it is highly unlikely that a supernova will result in a prompt fashion from the outward propagation of the shock formed at core turnaround. Several alternative models for producing supernovae from core collapse which involve either a late-time neutrino heating of the shocked matter, or a combination of rotation and nuclear burning in the oxygen rich mantle look promising.

10:30 am PSS-8 A Characteristic Study of Shock Waves in Supernovae. DEREK MEYER Harris Corporation, 2101 West Cypress Creek Road, Ft. Lauderdale, FL 33309-1892. Current models of supernovea involve the generation and propagation of a strong shock wave that travels outward through the star and ejects matter explosively. Much controversy surrounds the propagation of this shock. A numerical technique is being developed to compute the shock's evolution, treating it as a discontinuity and avoiding the use of artificial viscosity. This is of particular importance for both an accurate representation of the propagation of the shock wave and the flow of neutrinos across it. Results from this work will be discussed.

This research is being done in cooperation with Dr. Steven W. Bruenn of the Physics Department at Florida Atlantic University.

10:45 am PSS-9 Photoelectric Effects in Bilayer Membranes. JAY S. HUEBNER, Center for Membrane Physics, University of North Florida, Jacksonville, FL 32216.

Photoelectric effects (PEF) are obtained from bilayer membranes incorporating many different chromophores, for examples, chlorophyll-a (CHL) and rhodopsin. The electrical properties of membranes are described by simple RC circuits[1]. Many PEF result from simple photo-physical actions which displace charge within the membrane or capacitor dielectric. Tryptophan and CHL for examples are photo-ionized, so charge displacements result from electrons moving from the membrane into the polar aqueous solutions[2]. RC circuits bridge the gap between molecular processes and the observed PEF. The apparatus and procedures[3,4], which are routinely used by undergraduate UNF students, thus provide convenient means for studying important topics in the subject areas of biophysics, membrane physics and photo-physics.

1. J. S. Huebner, J. Membrane Biology 65 (1978) 147; 2. Huebner et al., Photochemistry and Photobiology (PP) 35 (1982) 467; 3. Huebner, PP 30 (1979) 233; 4. Huebner et al., PP (1984) in press.

11:00 am PSS-10 Propagation in an Amplifier of a Coherent Optical Pulse of Initial Area > 2π. HEENA R. NANDU AND JOSEPH R. COX, Physics Department, Florida Atlantic University, Boca Raton 33431. Inverse scattering techniques are used to investigate the propagation in an amplifier of a coherent optical pulse whose initial profile is a left-truncated hyperbolic secant of area A such that $2\pi<A<4\pi$. A two-level nondegenerate medium is assumed, and dissipative effects are neglected. In the limit of extreme inhomogeneous broadening, the exact solution for the pulse is obtained, and it is found to evolve into a π-pulse at the light cone which exhibits the expected amplification and compression, plus a phase-shifted 2π soliton of lesser velocity whose amplitude and width is related to a zero of the transmission coefficient in the associated scattering problem. This final area of 3π is in agreement with the area theorem of McCall and Hahn.

FRIDAY 11:15 am GCS 208
BUSINESS MEETING: Physical and Space Sciences
E.F. STROTHER, Florida Institute of Technology, presiding

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

RARE AND ENDANGERED BIOTA[1]

SATURDAY 9:00 am GCS 204
D.B. WARD, University of Florida, presiding

9:00 am REB-1 Endangered Plant Species of the Central Florida Ridge, Polk and Highlands Cos. SUZANNE TODD COOPER and GARY E. SCHULTZ, Florida Natural Areas Inventory (FNAI), 254 East Sixth Ave., Tallahassee, FL 32303. The Central Florida Ridge supports well over 20 endemic plant species. The once vast acreage of scrub and sandhill habitats occupying the Ridge has been drastically reduced and fragmented by citrus production and residential development as well as by the interruption of the natural fire regime. The FNAI conducted extensive field work during late summer 1983 to obtain current community- and species-specific information on Federal candidate and FCREPA-listed species. On each of 50 sites, ranging from 20-200 acres, the data collected included: a species list; estimates of % cover in the canopy, midstory and understory layers by species; evidence of fire or other disturbance; current and projected use. For each FNAI "special plant," data included number of individuals, reproductive vigor & success, associated species, and management needs. All of the data obtained has been entered into FNAI's integrated data base, which includes computerized and mapped information.

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[1] Florida Committee on Rare and Endangered Plants and Animals (FCREPA)

9:15 am REB-2 Preliminary Findings on Endangered Plants in Sand Pine Scrubs of East Central Florida. I. JACK STOUT, C. L. CONNERY and P. L. KLINGER, Department of Biological Sciences, University of Central Florida, Orlando, FL 32816. The objective of this ongoing work is to characterize sand pine scrubs of east-central Florida. One aspect of this effort is concerned with determining the status of plants currently included on either state or Federal lists as having some level of endangerment. Field work in 1983-84 concentrated on study of relatively undisturbed stands in Orange, Seminole, Brevard, Volusia, and Flagler counties. Qualitative and quantitative data were assembled from more than 30 stands. The status of selected scrub plants will be discussed with emphasis on the problems of preservation. The work was supported by funds from the Florida Chapter of the Sierra Club and the Florida Natural Areas Inventory.

9:30 am REB-3 Ecological Adaptation of Beach Peanut on Florida's Subtropical East Coast Beaches. GRACE BLANCHARD IVERSON, Department of Biological Sciences, Florida Atlantic University, Boca Raton, FL 33432. The Beach Peanut (Okenia hypogaea Schlecht. & Cham.) is an endangered plant species of restricted and diminishing occurrence along Florida's southeastern coastline. Its growth form depends upon environmental conditions. Occupying two ecological niches, the Beach Peanut maintains a stable population in the vine and grass zone and in mildly disturbed sites, while as a pioneer it takes advantage of annually renewed open beach.

9:45 am REB-4 1983 Sea Turtle Nesting at Kennedy Space Center and Cape Canaveral Air Force Station. FL. JANE PROVANCHA, M.J. PROVANCHA and C.T. GAETZ, Bionetics Corp., K.S.C., FL. 32899. Marine Turtle nesting densities, species composition and predation rate were studied on a 34 km beach using crawl counts gathered on 53 days of the 1983 nesting season. A total of 2,573 crawls (1554 nest and 1019 false crawls) were observed of which 98.2% represented Caretta caretta and 1.8% represented Chelonia mydas. The Caretta total nest estimate of 3,703 yielded a nesting density mean of 106 nests/km (range = 2-226). Nesting densities along the beach varied considerably and as suspected by previous investigators, the densities were lower south of the Cape (range = 2-58). Efforts were made to compare nesting densities and percent false crawls to natural physical features of the beach and nearshore zone and the activities of the space shuttle launch complex. Densities did increase with increased slope but also displayed more variance. A mean of 26% of the Caretta nests were predated within 12 hours of laying (range = 0-66%) while the predation rate of Chelonia nests was 13%. Funding was provided through NASA/KSC contract.

10:00 am REB-5 Notes on Two Endangered Pawpaws: Deeringothamnus rugelii and D. pulchellus. ELIANE M. NORMAN, Department of Biology, Stetson University, DeLand, FL 32720. Deeringothamnus (2ssp.) and Asimina (8ssp.), commonly known as Pawpaws, are the only two extratropical genera of the Annonaceae. Distribution of both ssp. of Deeringothamnus, based on herbarium and field studies, is extremely restricted. The rarity of these taxa is undoubtedly due in large measure to low fruit production and seed set which in turn are caused by 1) poor flower production 2) strong protogyny 3) low pollen to ovule ratios 4) and presence of very few pollinators. Hybrids between D. rugelii and A. pygmaea have been found. Deeringothamnus appears to be a relict which is found in areas of Florida which are being rapidly developed. The only way to preserve this genus from extinction is by land acquisition.

10:15 am REB-6 Reappearance of *Asplenium monanthes* in Florida. JAMES DAN SKEAN and DANIEL B. WARD, Department of Botany, University of Florida, Gainesville, FL 32611. The tropical fern, *Asplenium monanthes* L., exhibits a disjunct distribution in the continental United States, with documented populations in Cochise Co., AZ, Transylvania Co., NC, Oconee Co., SC, and Alachua Co., FL. The single Florida population, at that time consisting of ca. 150 plants, was discovered in 1949 in a deep ravine in San Felasco Hammock, ca. 10 km. nw. of Gainesville. The number of plants seen in subsequent years declined, possibly as a result of inundation and siltation of the ravine bed. Since 1969 repeated examinations of the ravine rocks have disclosed no plants. In December 1983 a single immature plant was found to have appeared, suggesting persistence in the gametophyte stage and opening the possibility of re-establishment of a species thought to have been extirpated from Florida.

SATURDAY 10:30 am GCS 204
BUSINESS MEETING: Florida Committee on Rare and Endangered Plants and Animals
D.B. WARD, University of Florida, presiding

SCIENCE TEACHING

SATURDAY 10:00 am GCS 201
P. PAPACOSTA, Stetson University, presiding

10:00 am TCH-1 Teaching in the Non-Classroom. D. TRAVIS SPAULDING, Science Education Center, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. With thoughtful planning and organization "non-classroom" environments such as zoos, botanical gardens, museums and popular tourist parks such as Sea World, Busch Gardens and Cypress Gardens, can become a valuable learning experience for students at all grades. How can these places of interest become useful educational experiences? This presentation supplies teaching methods for the best use of these non-classroom environments as well as ideas for creating one's own community based resource.

10:15 am TCH-2 Writing Assignments as a Tool in the Teaching of General Chemistry. PHILLIP B. HORTON, Science Education Center, Florida Institute of Technology, Melbourne, FL 32901. The recent concern over writing skills has led to an increased emphasis on writing assignments in science courses. Some writers have suggested that in addition to an improvement in writing skills, increased student understanding of course content should also result with the increase in appropriate writing assignments in science. Sixty-two students enrolled in college general chemistry were randomly assigned to two groups. Pretest results indicated that the two groups were equivalent. Each group was required to complete 8 written summaries of class lectures, but at different times during the quarter. The students who were first required to complete the 8 summaries served as the treatment group and had posttest scores that were 8 percentage points higher than the control group. Analysis of student responses to an end of quarter questionnaire indicated that students found the writing assignments helpful and favored their continued use in other chemistry courses.

10:30 am TCH-3 Florida's Crisis in Science Teaching: Implications for the Science Community. BARBARA S. SPECTOR AND BARBARA E. ROTHSTEIN, School of Education, Florida International University, Bay Vista Campus, North Miami, FL 33181; Southeastern College of Osteopathic Medicine, 1750 N.E. 168th Street, North Miami Beach, FL 33162. This participant observation study describes Florida's crisis in science teaching; who has responded to it; what they have done; and the expected impact on science. Data collected from state task forces, the legislature, scientists, precollege and college science educators, and business and industry reveal dramatic changes are occurring and have potential to impact the entire enterprise of science in Florida.

10:45 am TCH-4 A Chemistry Magic Show. DOMINIQUE MUSSELMAN, ROBERT KNOX, AND DAVID MILLER, Stetson University, DeLand, Florida 32720. The Gamma Sigma Epsilon Chemistry Honorary Society of Stetson University is currently offering "A Chemistry Magic Show" to the primary and secondary schools of Volusia County. The Chemistry Magic Show is a presentation of interesting and eye-catching experiments (Cold Light, Nylon Rope, Spontaneous Fire, Burning Handkerchief, Smoke Puff, Fog, etc...) designed to fascinate students of all ages. The two-fold purpose of "A Chemistry Magic Show" is: (1) to show that chemistry can be fascinating and fun, and (2) in doing so, generate more student enthusiasm toward the sciences. Audience reception during this year has been excellent. A sample performance from the Magic Show will be presented. The use and initiation of the Chemistry Magic Show by other schools will be discussed and greatly encouraged.

SATURDAY 11:00 am GCS 201
BUSINESS MEETING: Science Teaching
P. PAPACOSTA, Stetson University, presiding

SOCIAL SCIENCES

FRIDAY 1:30 pm Administration 201
PLENARY SESSION I: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

FRIDAY 3:00 pm ADM 201
BUSINESS MEETING: Social Sciences
W.D. TROPF, University of Central Florida, presiding

FRIDAY 7:30 pm Howard Johnson's Ocean Resort
BANQUET AND PLENARY SESSION II: Florida Academy of Sciences
F.B. WOOD, University of Florida, presiding

URBAN AND REGIONAL PLANNING

SATURDAY 9:00 am GCS 203
A.D. MERRIAM, Apalachee Regional Planning Council, presiding

9:00 am URB-1 Bicycle Facility Planning in the Gainesville Urbanized Area. MARLIE J. SANDERSON, AICP, North Central Florida Regional Planning Council - Staff to the Gainesville Urbanized Area Metropolitan Transportation Planning Organization, 10-300 S.W. 2nd Avenue, Gainesville 32601-6294. This presentation describes the Bicycle Facility Planning Program in the Gainesville Urban Area. This Program is used to reduce traffic congestion and obtain greater capacity out of the existing highway system. The Gainesville Urban Area has adopted a long-range transportation plan which is based upon ten percent (10%) of all Year 2005 trips being made by bicycle. This Plan is consistent with current Federal and State transportation policies which recognize their responsibility to ensure that bicyclists are appropriately considered in the planning, design, construction, and operation of highways. This presentation will discuss specific procedures which are being implemented to achieve the ten percent modal split goal.

9:15 am URB-2 Development Encroachment on Agricultural Lands, 1972-1980: Planning Region VII. NICHOLAS STASZKO, Central Florida Regional Planning Council, P.O. Box 2089, Bartow 33830. Rapid population growth is encroaching upon and converting once unique agricultural land in Planning Region VII, forcing agriculture further out into the fringes of urban development. Of primary concern is the suitability of these marginal lands for an agricultural use. For example, the evidence indicates that a significant amount of acreage located in lowland areas with high water tables has been converted to citrus production. It is known that citrus does not naturally thrive in these areas. Additionally, it has been discovered that large portions of wetlands have been converted to agricultural production. The purpose of this paper is to discuss the social, economic and environmental impacts that development encroachment places on agricultural lands.

9:30 am URB-3 Hazardous Waste Management: The Regional Planning Challenge in 1984. TIMOTHY C. VARNEY, Central Florida Regional Planning Council, P.O. Box 2089, Bartow 33830. With the enactment of the Federal Resource Conservation and Recovery Act in 1975, and subsequent enabling legislation in 1976-77, a concerted effort was begun to bring generators, storers, transporters, reprocessers, and disposers of hazardous-toxic waste under a uniform program of control and monitoring. In 1983 the State of Florida formulated and adopted into law the "Guidelines to Conduct County and Regional Hazardous Waste Assessments" (Chapter 17-31, Florida Administrative Code). The purpose of 17-31 is to implement provisions embodied within the "Water Quality Assurance Act" (Chapter 83-318, Laws of Florida). Central to the 17-31 rule is the major role Regional Planning Councils will play in hazardous waste management assessments and notification of small quantity generators within their respective regions. The purpose of this paper is to speak to the technical and administrative complexities contained within this most recent challenge facing the regional planning process.

9:45 am URB-4 Coastal Energy Facilities Siting Study and Technical Appendix, TAMPA BAY REGIONAL PLANNING COUNCIL, 9455 Koger Blvd., Suite 219, St. Petersburg 33702. The economic and environmental impacts and other information necessary to gauge the Outer Continental Shelf activities taking place in the Eastern Gulf of Mexico and their impact on coastal areas is examined, as is the potential and operations of onshore facilities which would be required should oil or gas be discovered in the Eastern Gulf of Mexico. Competed through grant from federal and state coastal programs, report provides scenarios for onshore facility development and addresses complex issue of facility siting in the Tampa Bay area. A matrix developed through special citizens advisory group is the key to future siting decisions. Nine candidate sites were examined and the matrix was used to reduce the potential sites to four. The appendix includes an analysis of federal, state, regional and local mechanisms as to their degree of effectiveness for controlling OCS development.

10:00 am URB-5 Tampa Bay Region Hurricane Loss and Contingency Planning Study, DAVID GRIFFITH, Tampa Bay Regional Planning Council, 9455 Koger Blvd., Suite 219, St. Petersburg 33702. The magnitude of property damage from a hurricane strike in the Tampa Bay Region is documented in this report. It estimates the extent and location of potential hurricane loss by first identifying property at risk through computerized storm surge modelling, done for the nation's first regional quantified hurricane evacuation plan, (Tampa Bay's 1980 Study). The types of structural loss quantified include residential, commercial, industrial and military. Finally the risk of loss is quantified through a probablity of occurrence analysis. The results in final estimates of potential hurricane loss are discussed as they relate to integration into comprehensive emergency management efforts. Policies for regional hurricane hazard mitigation are presented in this pilot Federal Emergency Management Agency-funded report.

10:15 am BREAK

10:30 am URB-6Vessel Traffic and Outer Continental Shelf (OCS) Energy Risk Analysis. M. BARRY PETERSON AND J. GOLDSTEIN, South Florida Regional Planning Council, 3440 Hollywood Blvd., Suite 140, Hollywood 33021. Intensified leasing of Federal lands located on the Gulf of Mexico and Atlantic Ocean outer continental shelves, for oil and gas development, has prompted concern over the likelihood of an increase in the probability of oil spills resulting from growth in vessel movement within and between those bodies of water, through the Straits of Florida. This study includes and evaluates information on oil tanker and other commercial traffic transiting the Straits of Florida and traveling along South Florida's coast, provides existing spill rate data, and projects the effect of additional traffic associated with normal growth and increased OCS activity. A comprehensive review of all oil and tanker information was undertaken prior to focusing on activities that could substantially impact the South Florida (Broward, Dade, Monroe, and Palm Beach counties) and its ports.

10:45 am URB-7 Hurricane Preparedness as an Element of Regional Planning. WAYNE E. DALTRY AND MARY GIBBS, S.W. Florida Regional Planning Council, 2121 W. 1st St., Fort Myers 33901. Hurricanes have become recognized as regional, as opposed to local, threats by disaster preparedness officials. Consequently, an effective response to this threat involves planning and preparedness actions at a regional or multijurisdictional level. The first component of a regional plan is knowledge of the threat. This information is provided through the National Hurricane Center by its SLOSH (or SPLASH) model. The remaining components include the population affected by storms, evacuation routes and their characteristics, and probable destinations. This information enables planners and civil defense officials to assure that timely evacuation orders are given and routes are adequately maintained regardless of community jurisdiction lines, with the overall purpose of preventing loss of life in natural hazards.

11:00 am URB-8 Levels of Hurricane Threat as Applied to the Emergency Hurricane Process. MICHAEL J. BUSHA and RUDOLPH MARCHESE, Treasure Coast Regional Planning Council, 620 S. Dixie Highway, Box 396, Stuart, Florida 33495. To relate estimates of hurricane disaster potential to relevant emergency planning, each category (Saffir-Simpson Hurricane Scale) of storm has been converted to associated Levels of Hurricane Threat (LHT). The specifics of each LHT provide the emergency planner with vital evacuation decision-making data for various approaching hurricane types, depending upon where the predicted landfall point will be in respect to his area of responsibility. The data identify the number of residents, by county, expected to be at-risk during various LHT and the number of hours available before oncoming hurricane forces make evacuation no longer feasible. It also provides the emergency planner with the minimum number of hours required to complete evacuation of the county under various conditions of ambient weather. By correlating these two times, disaster preparedness officials can determine the hour beyond which a successful evacuation can no longer be completed.

11:15 am URB-9 Developmental Benefit/Cost Impact Analysis for St. George Island, Florida. ANE D. MERRIAM, Apalachee Regional Planning Council, 425 E. Central Avenue Room 321, Blountstown, FL 32424. This project was initiated to evaluate the relative costs and benefits of new residential development on a barrier island in the Gulf panhandle region of Florida. The major items evaluated included environmental and economic costs associated with maintenance of water quality in the estuary, providing water supplies, transportation and routine infrastructure and services to new residents balanced by the expected new tax and fee revenues. A total annual per capita cost of $2,342 was identified for population increases up to 25,000 new residents and included the following services: general government ($62), police ($112), fire ($79), other public safety ($33), health ($23), culture ($18), water/sewer ($377), refuse/solid waste ($33), runoff/drainage ($100), normal transportation ($150), hurricane evacuation transportation ($200), schools ($855) and ecological monitoring ($300). If Franklin County was to be responsible for providing the services and the revenues for these services were to be derived solely from property taxes from the new residents (and not spread out over the existing tax base), the new homes would need to be assessed at a minimum of $300,000, to break even.

11:30 am URB-10 Effects of Environmental Regulations Applied at the Local Level. JACK Y. REMUS, Environmental Division, City of Boca Raton, 201 W. Palmetto Pk.Rd., Boca Raton, Fl 33432. Discussion of History, Purpose, and Methods of Implementation of Environmental Regulations as illustrated with examples from the City of Boca Raton and Palm Beach County. The Regulations shown to include Noise and Outdoor Lighting Ordinances, Tree Protection/Conservation Permit Procedures, Industrial Air and Water Pollution Standards, Landscaping Criteria, and Developmental Constraints based on Environmental Concerns in Planning. Examples will be given of Effects of these and other Locally Enacted and Enforced Regulations and their Benefits to the Community.

SATURDAY 11:45 am GCS 203
BUSINESS MEETING: Urban and Regional Planning
A.D. Merriam, Apalachee Regional Planning Council, presiding

AMERICAN ASSOCIATION OF PHYSICS TEACHERS
-FLORIDA SECTION-

SATURDAY 9:00 am GCS 217
J.A. MEYERS, University of Central Florida, presiding

9:00 am APT-1 High Pressure Studies of ^{121}Sb Isomer Shift in Noble Metal Alloys. LEE CHOW*, Dept. of Physics, University of Central Florida, Orlando, FL - 32816. PAUL A. MAGILL, JOSEPH N. FARRELL and LOUIS D. ROBERTS, Dept. of Physics and Astronomy, University of North Carolina, Chapel Hill, N.C. - 27514. Isomer shifts of ^{121}Sb dissolved in noble metal alloys $Sb_{0.02}$ $Cu_{0.98}$ and $Sb_{0.05}$ $Ag_{0.95}$ were measured as function of pressure up to 45 Kbar in a Bridgman anvil high pressure cell. Results indicate that in both cases the electron density at the nucleus, ρ (o) decreases as the pressure is applied. This trend is in agreement with the high pressure measurement in pure Sb metal. The measured values for the pressure derivative of isomer shift dIS/dP for $Sb_{0.02}$ $Cu_{0.98}$ and $Sb_{0.05}$ $Ag_{0.95}$ are 4.4 x 10^{-3} mm/sec. Kbar and 1.10 x 10^{-2} mm/sec. Kbar respectfully. These results and the isomer shifts of the alloys at zero pressure relative to the pure metal will be discussed in conjunction with a simple charge screening model of Friedel.

*Work done while at University of North Carolina.

9:20 am APT-2 Quantum Mechanics and the Principle of Equivalence. WELDON J. WILSON, Department of Physics, University of Central Florida, Orlando, FL 32816. It is shown using only elementary quantum mechanics that a particle violates the principle of equivalence. This violation of the principle of equivalence is most noticable for the low-lying quantum states and disappears in the classical limit. The discussion shows a basic incompatibility between quantum theory and the theory of general relativity and is suitable for use in a typical modern physics course after relativity and the Bohr atom have been covered. The topic is useful in introducing the student to one of the problems confronting present-day researchers in this area of physics who are attempting to formulate a consistent quantum theory of gravity.

9:40 am APT-3 D.C. Conductive Studies in Pyrolyzed Polyacrylonitrile. JEFFREY A. MEYERS, University of Central Florida, P.O. Box 25000, Orlando, FL 32816. Thin films of polyacrylonitrile have been prepared which are smoother than those previously reported. They have been pyrolyzed at temperatures as high as 500°C. Their D.C. conduction properties have been studied using both continuous D.C. and short repetitive pulses. The results tend to confirm the hopping model as the conduction mechanism in this material.

10:00 am APT-4 NSTA-CS^3- 1983 NSSA Search for Excellence is Physics Education - N. B. Forrest High School, Jacksonville, FL. RODERICK S. DICKENS, N. B. Forrest H. S., 5530 Firestone Rd., Jacksonville, FL 32210. The physics program at N. B. Forrest H. S. was selected as one of ten exemplary physics programs in the United States by the National Science Teachers Association in conjunction with a consortium of science teaching orginazations that includes the AAPT. Physics is offered at four levels in the Forrest Curriculum. The levels are reflected by the titles of the courses: Physical Science II, Physics I Standard, Physics I Advanced, and Physics II-C Advanced. These courses offer physics to students with a wide range of mathematical and analytical abilities. The Physical Science II course is targeted at the student who will not go to college and who has taken or is taking pre-algebra. It offers a one semester overview of physics. Physics II-C Advanced, which is a calculus-based Advanced Placement course, is at the other end of the spectrum.

10:15 am BREAK

10:40 am APT-5 The Open Lab for Physics. LOWELL SEACAT, Valencia Community College, Orlando, FL. 32802. For large beginning Physics classes there is never enough laboratory equipment for each student to perform an assigned experiment in the scheduled laboratory period. This results in lab groups too large to allow all students to become actively involved in performing an experiment. It is difficult for one instructor to provide sufficient detailed explanation of the mechanics of the experiment that students are trying to perform. Although it is not a panacea, the "open lab" concept offers some relief from these limiting factors that plague the conduct of experiments in the college physics laboratory. In this paper, we will discuss the efficacy of the "open lab" concept together with techniques of using the micro-computer and video tape to get maximum utilization of the limited amount of laboratory equipment for a large number of beginning Physics students.

11:00 am APT-6 The Newtonian Formal Format For Teaching Mechanics in Introductory Courses. William M. McCord, Valencia Community College, Orlando, Florida. The effort to teach introductory mechanics through the deductive process starting always from the Galilean - Newtonian propositional definitions and models of velocity, acceleration and dynamics will be discussed. The Piagetian perspective that a central role of introductory physics courses should be to raise the reasoning skills of all students from the concrete operational to the formal operational level will be touched upon. Also, a brief description of our current effort to accomplish the above under a State grant on "Excellence in Science and Math" will be outlined.

11:20 am APT-7 A Perceptual Quiz in Introductory Physics. ROBERT G. CARSON, Rollins College. For the past few years I have used a simple three-question, five-minute quiz to qualitatively explore students' thinking processes when they are faced with answering a question or solving a problem. The quiz, given during the first lecture-discussion session, has been used in a non-science major course as well as the traditional physics with calculus course. Since students don't identify themselves on the quiz paper and they aren't expecting a quiz on the first day, I believe that freer responses are given. The rationale behind the type of question asked and some statistics concerning student replies to each question will be presented. However, the audience will also take the quiz (unsigned, of course) before our discussion of the statistics to see how we compare with the students.

11:40 am APT-8 The Recent San Antonio Meeting of AAPT. Alex Dickison, Seminole Community College, Sanford, FL 32771. Highlights are presented of the joint annual AAPT-APS meeting held in San Antonio, TX on January 30-February 2, 1984.

12:00 pm APT-9 Physics and Creativity. GABRIEL J. MILANESE, Broward Community College, 3501 SW Davie Road, Davie, FL 33314. An approach to physics teaching that keeps intact the theoretical and mathematical foundation of physics, but also shows how physics as a science permeates our culture and society , is given. Moreover, the approach shows how physics is ultimately an intellectual pursuit that is appealing for its creativity and philosophical stimulation; a pedological approach that leads the student to an appreciation of art, music, theatre, poetry and philosophy through physics; and an important element of all fine arts.

SATURDAY 12:20 pm GCS 217
BUSINESS MEETING: American Association of Physics Teachers, Florida Section
J.A. MEYERS, University of Central Florida, presiding

NOTES

NOTES

"It is essential that the potential natural resources of Florida, geological, botanical, and zoological, be investigated. Not only do we need a knowledge of our total potential resources but we also need to know how far we dare or dare not to go with the modification, utilization, and exploitation of these resources. Here I would also include some of the resources of anthropological or even esthetic interest. If some or a part of these resources must be sacrificed at the altar of progress, then the least we can do is to create accurate pictures and records of what has been. Some of our native animals and plants together with their natural setting are at least leaning, if not actually going, toward annihilation; Indian mounds are going likewise; even natural wonders like sinkholes with their concommitant, peculiar life are choked with fenders, cans, and stoves of yesteryear. We should study, record, and map what still remains in primeval state. Florida ought not to leave its fate in the laps of geologists, zoologists, botanists, naturalists, foresters, or engineers, no matter how great their wisdom concerning the flora, fauna, or geology of other regions or lands, unless the experts in question have been on the ground long enough to be thoroughly familiar with all the aspects of the problem or problems. Major modifications of Florida land or water involving wild fauna and flora should not be permitted without the sanctions and counsel of thoroughly trained scientists fortified with years of local study."

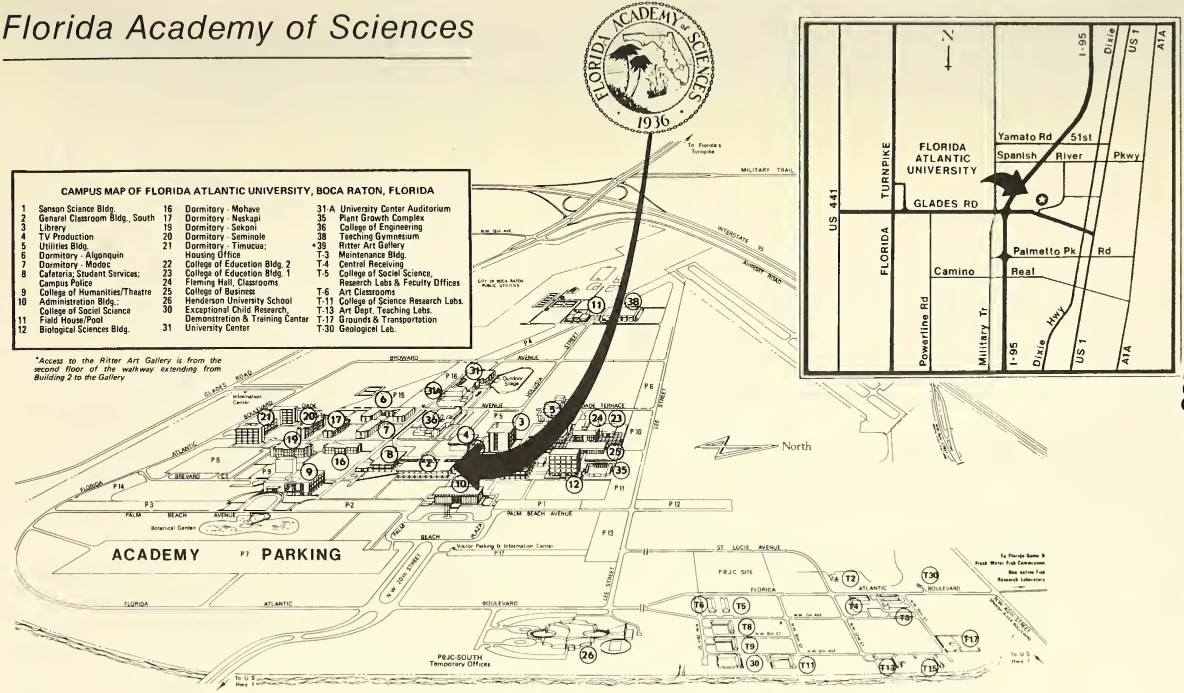
From an Address by Herman Kurz, Retiring Academy President, printed in Volume I, Proceedings of the Florida Academy of Sciences, 1936.

Florida Academy of Sciences

CAMPUS MAP OF FLORIDA ATLANTIC UNIVERSITY, BOCA RATON, FLORIDA

1	Sanson Science Bldg.
2	General Classroom Bldg., South
3	Library
4	TV Production
5	Utilities Bldg.
6	Dormitory · Algonquin
7	Dormitory · Modoc
8	Cafeteria; Student Services; Campus Police
9	College of Humanities/Theatre
10	Administration Bldg.; College of Social Science
11	Field House/Pool
12	Biological Sciences Bldg.
16	Dormitory · Mohave
17	Dormitory · Neskapi
19	Dormitory · Sekoni
20	Dormitory · Seminole
21	Dormitory · Timucua; Housing Office
22	College of Education Bldg. 2
23	College of Education Bldg. 1
24	Fleming Hall, Classrooms
25	College of Business
26	Henderson University School
30	Exceptional Child Research, Demonstration & Training Center
31	University Center
31-A	University Center Auditorium
35	Plant Growth Complex
36	College of Engineering
38	Teaching Gymnasium
*39	Ritter Art Gallery
T-3	Maintenance Bldg.
T-4	Central Receiving
T-5	College of Social Science, Research Labs & Faculty Offices
T-6	Art Classrooms
T-11	College of Science Research Labs.
T-13	Art Dept. Teaching Labs.
T-17	Grounds & Transportation
T-30	Geological Lab.

*Access to the Ritter Art Gallery is from the second floor of the walkway extending from Building 2 to the Gallery



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